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ABSTRACT

This document presents proceedings of a workshop held as part of Australia's preparations for the United Nations Conference on Science and Technology for Development, 1979. An overview of the workshop is presented, along with a transcript of the keynote address. Four topics are then addressed: (1) The Changing Allocation of Resources of Science and Technology in Australia; (2) The Impact of Science and Technology on Society and on Individuals; (3) Appropriate Education and Training in Science and Technology; and (4) The Transfer of Science and Technology. Also presented is a transcript of a panel discussion in which non-scientists and non-technologists questioned the participants of the workshop from a lay point of view on the application of science and technology for development. Appendices present statistical data concerning science and technology and a list of related activities in Australia. (CS)

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Science and technology for what purpose?

An Australian perspective

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SCIENCE AND TECHNOLOGY

FOR WHAT PURPOSE?

AN AUSTRALIAN PERSPECTIVE

Executive Editor

A.T.A. HEALY

Proceedings of a Workshop held as part of Australia's preparations for the United Nations Conference on Science and Technology for Development, 1979. The Workshop was jointly convened by the Academy of Social Sciences in Australia, the Australian Academy of Science, and the Australian Academy of Technological Sciences at the Australian Academy of Science, Canberra, 18-20 April, 1979.

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PREFACE

The United Nations Conference on Science and Technology for Development (UNCSTD), to be held in Vienna in August 1979, is aimed to assist the so-called 'developing' countries to attain higher standards of well-being. The initiative for the present Workshop came as a result of discussions between the Australian Academy of Science and the Australian Department of Foreign Affairs. The Workshop was one of a number of activities sponsored and encouraged by the Australian Steering Committee on Preparations for UNCSTD as part of Australia's preparation for the Conference.

The Workshop has been organised by a joint committee of the Australian Academy of Science, the Academy of the Social Sciences in Australia and the Australian Academy of Technological Sciences.

The committee was faced with a number of questions in deciding what to do. One problem was that the National Paper, concerned directly with the Australian attitude to the main question of the Conference, had already been prepared. There have also been other discussions relating to developing countries, notably the 'mirror' conference of Asian and Australian representatives organised by the Australian UNESCO committee.

The Workshop committee considered that there were two valid bases for a further look at the topic, which, while not neglecting the main issue, may contribute to Australia itself. The first was in the form of this discussion, which centres around a series of personal contributions put forward as opinions and ideas, not necessarily as a widely agreed consensus. The consensus may come, if at all, from the Workshop discussions. The other basis was the assumption that, in the face of the scientific revolution, all countries are developing ones, even those which benefited from the industrial revolution. This applies to Australia itself, which must reconsider many aspects of its social organisation and national objectives. Indeed the gap between 'developed' and 'developing' countries, in terms of their need to consider problems carefully, is being narrowed by this new revolution.

The committee also believed, that in view of the broad world contribution to the UN Conference, the Australian contribution could best be made by considering the historical Australian experience, in the light of national aspirations and possible future developments.

Science and technology are tools for community use: the keynote is set by the first contribution 'Science and technology - for what purpose?'

The committee attempted to choose those people who might best expose the issues, and suggest some approaches to solutions. The opinions expressed are those of the participants and not necessarily those of the Academies. The names of the Workshop participants are given in the following section, together with the discussion group to which each contributed.

To extend the public discussion beyond this invited Workshop, the Academies committee has done its best to foster one-day public Symposia, following this meeting, and they are providing modest funds from their own resources for this purpose.

Acknowledgements

The committee would like to record its appreciation to those people who made the Workshop and this publication possible. Early discussions with Mr Guy Gresford, then the Chairman of the Australian Steering Committee on Preparations for UNCSTD, were particularly fruitful. Continuing assistance and advice has been provided by Mr J.P. Shelton and Mr I.D. Gordon of the Department of Foreign Affairs. The joint efforts of the three Academies have been harmonious and rewarding. Special thanks are due to the authors who accepted the Committee's invitation to prepare papers for discussion and the Workshop participants who contributed so willingly. The organisation of the Workshop devolved on the willing shoulders of Robin Brown and Maureen Kaye, who put the committee's wishes into practice. The Commonwealth Scientific and Industrial Research Organization (CSIRO) provided the editorial supervision of Dr Ken Ferguson, Tim Healy as Executive Editor, and the sub-editing expertise of Elizabeth Odgers. Angela Hughes, Pavla Staples and Phyllis Franzen of the CSIRO Word Processing Centre typed and updated the manuscript; the speed with which the proceedings of the Workshop have been produced is due largely to their efforts.

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WORKSHOP OVERVIEW

BY

A.J. BIRCH

Professor Arthur J. Birch, MSc (Syd. & Manc.), DSc (h.c.)(Syd.), DPhil (Oxon.), FRIC, FRACI, FAA, FAS, graduated MSc from the University of Sydney and went to Oxford on a Scholarship of the Royal Commission for the Exhibition of 1851, to work with Sir Robert Robinson. After graduating DPhil in 1940 he began war research which led to the 19-norsteroid series, and his metal-ammonia reductions of aromatic rings. This work led ultimately to the availability of oral contraceptives. In 1949 he went to Cambridge, to Lord Todd's laboratory. In 1952 he became Professor of Organic Chemistry at Sydney University, and in 1955 became Professor of Organic Chemistry at Manchester University. He founded, in 1967, the new Research School of Chemistry at the Australian National University, and was Foundation Dean, from 1967-70. He was also Dean 1973-75.

He has been Treasurer of the Australian Academy of Science. He was elected a Fellow of the Royal Society in 1958, of the Australian Academy of Science in 1954 and of the Academy of Sciences of the USSR in 1976. He is also a Fellow and Past-President of the Royal Australian Chemical Institute, The Royal Society of NSW, Royal Institute of Chemistry and American Chemical Society.

His active interests embrace the history of scientific ideas, science policy in government, the educational and philosophical value of science, and the relationships between arts and sciences. From 1974-75 he was a member of the Advisory Council, Science and Technology to the Australian Government. Professor Birch was responsible for organising the Science Exhibition of the National Festival of the Arts and Science for Australia 75. From 1976-77 he chaired the Independent Inquiry into the CSIRO and is the Chairman of the Joint Academies Organising Committee for UNCSTD.

INTRODUCTION

The 'Science and Technology for what Purpose' Workshop has been an attempt by three premier academic bodies with relevant areas of interest (science, social science and technology) to bring the highest academic level considerations to bear on the problems of applying science and technology for development and especially Australian assistance to the less developed world. This Workshop was only one of many contributions to Australia's preparations for the United Nations Conference on Science and Technology for Development, and it should be recalled, in considering its proceedings, that its approach does not stand alone, that it was aimed to fill a place in the diversity. A list of other activities is to be found in Appendix B. Our approach was to use Australian experience gained internally as a developing country over the last two centuries and externally from our relations with countries like Papua New Guinea, whose development came later; to try to distil, with high level academic methods, principles and practices of general application.

This approach was adopted because development is not a solely Third World problem which the First World can help to solve, but rather a truly global problem to which all nations must address themselves. This is consistent with the United Nations' desire for a new international economic order. It is recognised that economic development is only one of the goals of human endeavour contributing to social development, in the broader sense, intellectual development and spiritual development.

I think it is important to make clear what sort of development we are talking about. During the Workshop many of the deliberations were concerned with purely economic development. Perhaps an alternative vocabulary would be better. Rather than using the terms less-developed countries (LDCs) and developed countries (DCs) we should talk of less economically developed countries (LEDCs) and more economically developed countries (MEDCs).

This overview is intended to reflect the tenor of the comments and discussions of the Workshop participants, who were encouraged to put personal views rather than to review general opinions. It does not attempt to reach a consensus of the opinions expressed. The discussion papers in the body of the text provide a record of the Workshop discussions while the introductions to each theme reflect the main points made by the invited authors of contributed papers.

In examining Australia's own experience, we can hope to contribute to our own further development, in the context of the scientific revolution which is requiring fundamental re-examinations of social and economic organisations in all countries. The discussions of the Workshop were aimed to elucidate those parts of the Australian experience and approaches that developing countries might consider to be relevant to their own situations and needs. We are not in the business of telling other countries what they should do. Each country differs in social organisation and objectives, in stage of development and available resources. Each alone can make valid decisions about its own destiny.

THE CHANGING ALLOCATION OF RESOURCES OF SCIENCE AND TECHNOLOGY IN AUSTRALIA

Both politics and science in developing countries tend to lack maturity in the Western sense, although no general statement which embraces them all is possible. Inefficiency and corruption in both politics and business and low levels of indigenous science and technology are, in many cases, factors which have to be seriously taken into account and accepted. Maturity in administration and in science and technology will take time. Nonetheless, while this is being attained, many immediate problems must be tackled in ways appropriate to the present situation, while trying to hasten maturity where possible.

Scientific and technological resources have been highly concentrated in Australia, with R&D predominantly in Government supported institutions. There has been a considerable emphasis on agricultural and related biological research, because of the historical importance of primary industries and because these, apart from mining, have been too fragmented to carry out their own R&D. The emphasis has been changing towards technology and secondary industries since the beginning of the last World War. However, because of the organisation of industry into very small firms, with few exceptions, self-help encounters great problems. Some of the Australian experience is appropriate for other countries developing from an agricultural base towards industrialisation.

Politics and the interpretation of national needs has had a strong influence in Australia on the organisation and broad emphases of R&D, but only indirect effects on specific programs. Australia, in contrast to many developing countries, has a strong and mature base in science, and it is very doubtful whether the CSIRO model, which needs this base, can be transplanted elsewhere. Political and social pressures need to be manifest, but in ways which take account of scientific and technical potentialities. Matters like the extent of political control, the degree of dispersion of authority, the extent of bureaucratic methods and the involvement of scientists and technologists in decision-making have to be worked out for each national situation and degree of development. An appropriate mix of centralisation in general organisation and pluralism in application has to take account of the structures, needs and resources of a specific country.

The allocation of funding, and scarce resources such as trained people, is the crux of the problem. Even in developed countries, such as Australia, the trend has recently been towards more mission-orientated work, with the recognition that the connection between levels of pure science and technological advance is very general, international and long-term. Highly elaborate advisory systems, such as ASTEC and AMSTAC, have been set up in Australia. The approach is 'science for policy' to ensure that decisions at political and managerial levels are made in the light of the best available scientific opinion. There are problems in organising, notably that only a small minority of scientists is capable or interested, and that inputs from social science are probably insufficient. The approach requires a considerable reservoir of experts, in order to choose the few who are suitable. Many developing countries lack the broad academic base, and there is a tendency for scientists who serve too long in these ways to become bureaucratically-minded. Again, the Australian model may be difficult to apply elsewhere in the absence of the wide base of both professional support and professional criticism needed.

The rigidity of institutions, in the face of changing requirements but ageing and inflexible staffing and organisation is a general problem, exacerbated when there are few opportunities for people to move (or be moved) elsewhere, because of the existence of few or highly centralised institutions.

Any means of encouraging mobility of individuals, and continuous and automatic reassessments of the work and role of institutions is to be encouraged. Much of this has necessarily to come from inside, and be built into the organisation. Some suggestions of principles are to be found in the Report of the Independent Inquiry into the CSIRO.

University research has the objectives of contributing to a discipline and training individuals. There is no reason why it should not also be mission-orientated, not in the sense of attacking immediately definable tactical problems, but rather in the sense of laying a basis for a problem area. The case for funding relevant projects, as distinct from good people with projects considered only on scientific merit (ARGC) needs looking into. There is in some developing countries a considerable disproportion of fundamental, discipline-orientated work, in situations where this is a luxury. Scientists should not be misled into equating excellence only with pure fundamental research.

A wider involvement of the informed public in issues should be encouraged, perhaps through 'green papers'. Without a well-developed infra-structure of education and understanding such an approach could, however, hinder rather than help, desirable change.

ECONOMIC AND SOCIAL CONSEQUENCES OF SCIENCE AND TECHNOLOGY

Throughout the discussions, the emphasis was that set by Dr Coombs in his introductory remarks, 'science and technology for whom?' Science and technology, and the associated technical, political and administrative mechanisms, should be regarded as tools to fulfil social purposes which benefit all individuals. What was touched upon, but not sufficiently argued, probably because of its extreme difficulty, was the question of objectives. What is a desirable index of quality of life which can be made the aim of development?

A 'quality of life' index cannot be related directly to gross national product per head of population because this fails to measure either the appropriateness of what is produced or the equity of distribution. Distribution in relation to expectations and social ethics is at least as important a quantity. What is considered dire poverty in Australia might, materially, represent incredible affluence in many villages in developing countries. Social, ethical and moral questions indeed appear to raise more problems than do purely technical questions.

However, some kind of index of quality of life can, and should, be set up, which, while it may not measure the subjective values of happiness and fulfilment, at least may provide the basis for their attainment. Infant mortality, longevity (and its distribution in the population), general nutrition levels, housing standards, general (and appropriate) health care, literacy and opportunities for creative activities and amusements are all factors which can at least be semi-quantitatively examined.

Great uncertainties relate to the economic and social consequences of introducing new technology. Even in the more developed countries, such as Australia, the possible relationship between unemployment and new information technology is leading to a questioning of benefits.

Despite adverse unintended consequences, long-term benefits to quality of life can be foreseen, at the expense of temporary social disruption. Sharp differences of view were revealed by discussions, both on causes of adverse economic changes, like unemployment, and of the predictability of the results of technical change. What did seem to be agreed is that a major problem is the shortening of the time-scale in which innovations become effective. The major changes of the first industrial revolution operated over several hundred years, allowing some opportunity for people and institutions to adjust. Reduced to a few years, the scientific revolution, particularly in relation to microprocessors, could have very dramatic effects. Two contrary views were expressed. One that microprocessors can lead to the capability to do all sorts of things which were previously impossible and therefore to an increased potential for a higher quality of life, and to demands for new services in new areas. The contrary view held that the economics of adoption of labour-saving machines would, certainly in the short-term and probably in the long-term, lead to a permanent body of unemployed, and probably unemployable, people. Two suggestions concerned the need to examine socially valid ways to meet such a situation, and also the greatly increased study of the economic and social effects of new technology. Without such knowledge rational attempts at control are not possible.

Developing countries suffer additional trauma in connection with introduced technology which may be unsuitable to their optimum development. Many such countries, which are poor, non-homogeneous and with large populations, need initially improved agriculture rather than manufactures. Other, usually smaller and more homogeneous groups have succeeded in exporting a growing volume of labour-intensive manufactures based on imported technology and rather low but rising wage standards. They need foreign capital rather than governmental assistance.

Cautionary notes were sounded by the Workshop. The introduction of new farming techniques, for example, despite higher food production, has often led to rural unemployment, greater inequality in incomes, and a permanent loss of subsistence peasant farming with an accompanying growth of a landless and rootless group of people. However, this is not an inevitable consequence, given foresight and political will.

Successful transfers of technology depend on ability to absorb them based on adequate literacy, technical training, and adequate preparation for transfer such as the removal of language barriers.

One interesting discussion concerned the tourist industry, which as labour intensive and high return, particularly in foreign currency, might be regarded as ideal. However, it also has social disadvantages, involving a degradation of aspects of indigenous culture, in rising urban costs, and encouragement of undesirable practices such as use of drugs and prostitution. The juxtaposition of wealth, and social views and practices based upon it, with indigenous poverty, poses in this instance, as in others, the problem of assistance without social dislocation. The discussions revealed no complacency, but a strong desire to take practical steps to seek provision of benefits with maximum mitigation of undesirable consequences. The first step was thought to involve more research and evaluation by combinations of scientists and social scientists.

ECOLOGICAL AND HEALTH CONSEQUENCES OF SCIENCE AND TECHNOLOGY

Science and technology can be seen as tools to be used to free the bulk of mankind from uncongenial tasks and to ensure at least a minimum of well-being for all. Science, which is the understanding of how the universe works, and technology, which should be the application of this for individual benefits, will always be needed to ensure that there exists a stable state of dynamic equilibrium related to changing resources and changing social views. What is needed in addition is the social and political will to apply science and technology appropriately. Pluralism of needs and solutions must be recognised and encouraged since there will, desirably, always be differences between people and between groups of people in their needs and attitudes.

The ecological and health impacts of science and technology cannot be examined in isolation; they are part of the whole process of change and development, in which they are critical, but not necessarily dominant, components. Improvements in health, for instance, have not, until recently, been due to changes in 'medicine' but rather to improved nutrition, clean water supplies and a general understanding of a healthy existence. These all grow from scientific understanding; why water should be purified and how; the necessity for fertilisers and how to make them; breeding new crops; vitamins in nutrition; the relationships between causes and effects and how these can be influenced by practical measures. On the whole, technical medicine, with drugs, anaesthetics and complex operative procedures, has been reflected in a higher quality of life, but only for a small part of the world's population. The scientific devices which can now have most effect on the quality of life are those related to population control. Otherwise it is largely a matter of applying what is already known; a clean water supply to a village may make a far larger contribution to health than a modern hospital.

In terms of practical aid programs, what is needed, above all, is a long-term evaluation of all of the consequences of an action, such as building a dam, with a strenuous attempt to take into full and valid account the social organisation, economics and desired life-styles of those affected. Many countries lack the information and the people needed to provide the information, on which such judgements can be made. This puts an even larger responsibility on a donor country to make sure of the implications of what it is really doing: aid 'packages' cannot be regarded in limited terms, as self-contained gifts. A clear four-stage set of criteria were proposed that aid be examined by the donor in conjunction with the receiver: the proposal stage, the evaluation stage, the implementation stage, and the review and monitoring stage. Where there is a shortage of experts to carry out such examinations, Australia or other developed countries may be able to help, but the aim should, as far as possible, be local self-reliance, local control and local management. The problem is often compounded by the cleavage in social attitudes between those locally concerned with the decision and management of a project and those affected by it.

It was suggested that the Australian Environment Protection (Impact of Proposals) Act should be implemented for all major development transfer programs, both in the public and private sectors. While the intention is a good one, it might well be seen as infringing the sovereignty of the recipient. The ADAB Consultative Committee on Research and Development (CCRD), or a Standing Committee of Parliament might be given a review role. A further suggestion was that a 'Small Projects Division' of the Australian Development Assistance Bureau (ADAB) should be created and separately funded. In the past, the emphasis seems to have been too much on rather grandiose projects, rather than on small ones which are much more readily organised and make more immediately useful but often less disruptive impact. Indeed a major difficulty with large projects is in tending to produce a rate of change which is unacceptable in social terms.

More funds should be provided for independent advisory teams, along the lines of UNDAT, which are not directly linked to either the donor or recipient.

APPROPRIATE SCIENTIFIC AND TECHNOLOGICAL TRAINING IN AUSTRALIA

A major problem is that of education. Basic literacy is needed to provide the basis for any advance. The problem is that of training not just the scientists, technologists and technicians, but of a fair proportion of the general community in the kind of logical cause-and-effect thinking characteristic of science. Some general understanding of what science and technology can and cannot do is also needed. What are scientific questions and what are moral, ethical or aesthetic questions? In parallel, too, scientists, technologists and technicians need to become more aware of general community needs, feelings and reactions to their advances and changes. If a reasonable proportion of a community is to decide on the appropriate uses of science and technology, and the most likely future consequences of decisions, a widespread, two-way understanding must be encouraged.

The considerations of education in science were divided into education in science (for applications in science and technology) and education about science (for society at large, and particularly the decision-makers). Scientific education under either heading should aim to confer scientific modes of thinking and the ability to handle problems over broad areas, rather than merely formal training, although this has its place.

In Australia, there seems to be a decrease in student interest at schools and universities, perhaps associated with disillusionment, perhaps with a belief that science is 'difficult'. However, an increased interest in school biology in undoubtedly partly associated with the availability of the Academy of Science learning system associated with The Web of Life. The success of this program is due to its indigenous nature, that it is part of a system involving teacher training and that it was prepared by a joint effort of scientists and educators. The general point was made for the necessity in developing countries to provide appropriate high-level indigenous materials for teaching, rather than to attempt to transplant methods from one social and physical environment to another.

At high technical levels of science, including colleges and universities, the need is to emphasise the formulation and solution of problems rather than the cramming of facts. The value of work experience during courses was emphasised. Engineering and technology are often regarded as intellectually inferior to pure science. This is not so, and the products of high level training are much more immediately useful to developing countries than pure scientists. In fact, it is apparent that Australia needs a centre of excellence for the advanced education of engineers.

There is a need for appropriate continuing and adult education, in addition to formal primary, secondary and tertiary education. A whole spectrum of requirements can be seen, varying from professional up-dating to cultural aspects. Such education is related partly to the rapid rate of change and partly to providing further opportunities as people perceive the change and are able through higher living standards to take advantage of the opportunities. Australia is already regarded in S.E. Asia as a major source of consultation in the conduct of continuing education. The major problem in many developing countries is the provision of basic literacy to adults. Although not so directly in Australian experience, our related problem is that of providing literacy in English to migrants with other languages, and their incorporation into a new social setting. Australia, because of its relative affluence and sophistication, also has a number of non-government community organisations which could assist to train 'community animators' from elsewhere.

Australia itself would benefit from wider science library facilities; the provision of a Science Centre; the encouragement of the media to involve the public in debate on decisions involving science and technology; and encouragement of professional bodies of scientists to be more involved in public affairs and public education.

Direct intervention in education in developing countries was viewed with caution. The basic suggestion was to pass our ideas and attitudes through people rather than to provide very direct education except perhaps in purely technical areas. The development of indigenous education opportunities should be encouraged and assisted wherever possible.

TRANSFER OF SCIENCE AND TECHNOLOGY WITHIN AUSTRALIA

Much play is now made with the term 'appropriate technology', which is increasingly relevant in Australia itself, with the fuel crisis, the incidence of pollution and decreases in non-renewable resources. It is not in fact realistic, in the context of available resources, even to attempt to improve standards of living in all developing countries to the same plane as those in the more developed nations. The question, indeed, is whether it is desirable.

Technology transfer involves the generation, development, diffusion, adaptation and application of technology. The discussion was largely concerned with existing technology rather than with what is loosely called 'appropriate' technology, which is in any case a method of assessment rather than a different category.

Technology development is required to maintain, or increase, standards of living, a feat becoming increasingly difficult in the face of shortages of resources and energy. It is needed to make use of alternative materials and products, and to maintain defence preparedness and a balance of trade with the rest of the world.

These statements are true of Australia, and also with varying emphases elsewhere. Countries are interdependent, and considerations of what developments are appropriate at any given time must also take this into account.

Australia, since the last World War, which itself led to the development of industrial capacities, has had a considerable experience in importing industrial innovation. This has had important consequences in employment (which has fallen in the primary sector), in making possible immigration, and in providing a degree of national self sufficiency. The gaps exposed were to a large extent filled by imported technology.

How has Australian receptivity of technological innovation been facilitated since the World War? The mechanisms include the setting up of industrial laboratories, although on an insufficient scale, a large CSIRO effort to assist in instrumentation and equipment, a great increase of training and research by universities and the more recently set up Colleges of Advanced Education, and a general level of increased effort in Government laboratories and a few large companies. All of this has needed a great increase in Government funding, not all of it very wisely applied.

Australian technology, like that of other developing countries, to which category it belongs in this context, has been overwhelmingly derived from abroad. This is no great cause for alarm, since it is true for all countries, even the US, except that the estimated figure (95%) is very high. 'Science-push' has characterised the public sector, and this has been responsible for the provision of an extensive and highly sophisticated base for Australian science, which provides some 2% of world publications in pure science. It seems appropriate now that 'market-pull' should be more consciously incorporated into priorities. A concern is with the availability of those who create, adapt and use technology, and with the processes by which scientific ideas and inventions evolve into useful processes.

Resource industries such as the rural and mining sectors represent relatively few products, although a wide range of conditions. The problems are usually fairly obvious, and the solutions applicable on an industry-wide basis. The CSIRO-type organisaton proved particularly suitable to cope with needs in such areas.

Transfer of known technology to small firms, let alone the generation of new technology, has been difficult because a minimum scale of effort is needed to make any impact at all. Indeed, the problems of small manufacturing firms are often managerial and financial rather than technical. The direct provision of government support to small firms is often inappropriate, because it cannot be properly used. Large strategic mission-orientated organisations such as CSIRO are not suitable for industrial innovation at these levels, in part because they have no realistic interaction with the market place. One possible solution, which has not been extensively tried in Australia, is that of

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industry research associations, partly supported by government, which could provide the level of skills and equipment required to service small firms. Problems of these types are presumably even more acute in the industrialisation of developing countries previously based on agriculture. To a large extent the solution is the provision of informaton already available, rather than anything very new. Provision of government contract R&D, for example, in relation to Defence, is one desirable way to build up industrial capabilities. Further development mechanisms to put the result of scientific discovery and invention into usful practice are required to narrow the gap, found not only in Australia, between government and university research and the needs of society. This also requires considerations of patent policy, since, contrary to some beliefs, patents exist to ensure that inventions are properly developed, not just to make money for inventors. Diffusion of knowledge contained in patents is one ingredient of the information spread required.

Looking to the future in Australia, but with a belief in general relevance, some points can be made. Successful programs are dependent on having the right people in the right place at the right time. Mobility of people between institutions and between areas of work, between governments, universities and industry, must be organised and encouraged. Awareness of possibilities, and readiness to accept innovations and the changes associated with them are matters for education, involving science but not science alone. In transferring technology, major decisions concern selection of that to be transferred. This has to be made by a combination of those who really understand the technology, and those who really understand the uses and implications of it in relation to national needs, opportunities and aspirations. In the implementation of scientific and technological creativity in new areas, a research-development corporation, to provide finances for development and contacts with the world of commerce, is needed.

There are no automatic or simple solutions to problems of transfer, within or between countries. What is needed is an organic approach to permit opportunities to be perceived, and practical mechanisms to permit them to be grasped. The aim should not be technology for its own sake, but as a tool for the continuing benefit of the maximum number of people.

TRANSFER OF SCIENCE AND TECHNOLOGY TO DEVELOPING COUNTRIES

The transfer of 'aid' or development assistance is a very subtle business. Neither administrative systems, nor goods and services can be successfully incorporated into a new environment without the most careful adaptation to that environment. 'Aid' frequently has quite unforeseen consequences and there may be very deleterious effects on balanced but fragile traditional systems which lack elasticity due to poverty, and poor education. In particular, those who are involved in 'aid' programs must appreciate the social and political subtleties of the system they are 'aiding' and not behave just as experts in their particular technical field. Social and religious ethics may crumble rather than change for the better.

The aims of development assistance should take full account of the need for reducing inequities in living standards to ensure the equitable distribution of the fruits of progress as well as increasing the total potential of a country, for example in food production. The discrepancies in many developing countries in education, sophistication and material well-being, between those who rule and the bulk of the people are usually far more marked than in Australia. It is the very small but powerful ruling group which interacts with aid agencies, and its members may often think and behave more like members of the so-called First World than the majority of their own people.

Whether the transfer of S&T takes place commercially or through government, mechanisms should be set up for the dissemination of experience gained by Australians in the process. One result of the preparatory UNCSTD discussions has been the realisation that Australian scientists, social scientists and technologists have had experience in working on a great variety of projects in many countries. The problem is how to identify and channel this expertise. It was suggested that this aspect should be followed up by the three Academies. To avoid undesirable results there is a need for careful planning and monitoring by multi-disciplinary teams which include social scientists, a need to develop carefully integrated programs, and a need to adopt the principles 'start small, hasten slowly and retain the flexibility to make necessary changes in the light of experience'. Valid consultations of those whose lives would be changed was emphasised.

Only about 2% of the world's resources in science and technology are devoted to the problems of developing countries. In Australia, two things might be done: encouragement of Australian scientists, social scientists and technologists to include such problems in their projected work, and the provision by the Australian Government of separate funds for grants in aid of such work. CSIRO is empowered and already does do some work in this category.

It was considered that many Australians who work abroad are insufficiently briefed in the political, geographic, economic, religious and social conditions into which their work must fit at the start. They must above all be sensitive and sympathetic. Their selection and preliminary training is important.

The relevance of some of the training given to Third World students in Australia was questioned. The aim should be training for self-reliance at three appropriate levels: for survival; for elevation of living standards; for high technology. Training should generate the ability, by depth of understanding, to cope with new situations, not just to learn a particular job. The availability of such people in a recipient country is an important consideration in assessing the feasibility of new projects and programs.

In training technicians in Australia, opportunities exist in universities, colleges, industry and CSIRO. It was considered that it is best accomplished through small groups, rather than isolated individuals, and with intensive practice rather than more academic courses. Selection of appropriate people, with a reasonable working knowledge of English, is most important. Some provision for language teaching might be made before they come here. Training of technicians and technologists for short periods has a more immediate impact than the training of scientists, many of whom become psychologically uprooted and lose the desire to return home.

SCIENCE AND TECHNOLOGY ON TRIAL

In the midst of the deliberations, a panel from the community, partly representative of the antagonistic views of the applications of science and technology, put 'science and technology on trial' and produced considerable indignation and shock among the scientists. The scientists view protesters as totally failing to realise the opportunities conferred by science and technology, which they take for granted anyway, and as concentrating instead on the admittedly bad aspects. The serious point, however, is to ensure that the bad do not overwhelm the good, and that developing countries are at least warned, and are thus given the opportunity to avoid blundering into the difficulties which we have encountered. It is clear that man is now as effective as all other natural processes in changing the earth, often for the worse, and that this situation cannot be allowed to continue, let alone accelerate.

To be fair to the participants in the Workshop, there are few points of criticism made by the Panel which do not appear somewhere in the papers or discussion, and the approach was marked by the typical openmindedness characteristic of science to examine all possible issues. This is indeed a criticism by many opponents of the scientific approach who suggest the necssity for a preconceived idealogical base of thinking.

CONCLUSION

A number of practical suggestions on ways in which Australia can help developing nations emerged from the discussions, and for the details it is desirable to consult the full document. However, the basis is worth consideration. Australia, despite its prosperity, is historically a developing country which has largely had to develop its own agriculture in a social and geographic environment of isolation, and which has had to import most of its technology. By any yardstick, Australia has been very successful with the indigenous development of its agriculture and its pure science (to which it is a major world contributor) and fairly successful in choosing its technology from the world. In manufacturing industry it is, however, still in some difficulties, and its experiences should lead to some general lessons for itself and for developing countries.

As a country which has resources of wealth, political and scientific sophistication, and high education levels in a region of nations which is still developing, Australia has both regional obligations and opportunities to assist other countries in that region. It is willing to accept these opportunities by offering both direct assistance and educational facilities and experience. In doing this, Australia has to exercise a high level of tact and restraint. It must recognise that it can only try to act as a catalyst and that changes of lasting value in developing countries can only come from indigenous decisions, and not by the imposition of outside views.

Australia has a widely developed series of community structures, mostly initiated by individuals or small groups. It is also developing its own systems of adult and further education, and is already being asked to advise in the region on how such systems should be organised. The objectives of all these structures and educational systems are clearly even more necessary in developing countries than in Australia. The involvement of adults in social interactions and learning processes, including education in relation to change outside the formal educational sphere, is of utmost importance in a nation's development.

The value of the UNCSTD preparations would have been enhanced had the composition of the Australian Delegation to Vienna been known, and its members involved. It is suggested that a technical advisory group should accompany the delegation, despite the avowed aim of having political delegates making political decisions.

The Workshop was unusual in the effectiveness of the collaboration achieved between people of different academic persuasion. A proposal for the continuation of this cooperation via a Joint Academies Committee on Science Technology and Development was therefore met with some enthusiasm. The proposal suggested that such a committee might act to encourage further academic, professional and public debate on the subject, encourage relevant research and advise government and other institutions. In particular, the committee could assist in the analysis of the resolutions of UNCSTD itself and their implementation as appropriate. It could also act as the national agent for relevant non-government international organisations such as the Committee on Science and Technology for Development of the International Council of Scientific Unions.

The Workshop agreed to recommend to the Councils of the three Academies that consideration be given to the establishment of a permanent Joint Academies Committee on Science Technology and Development. The Workshop Organising Committee was left to prepare draft terms of reference for such a committee.

SCIENCE AND TECHNOLOGY - FOR WHAT PURPOSE?

BY

H.C. COOMBS

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Dr Coombs was Chancellor of the Australian National University from 1968 to 1974. He was Chairman of the Council for Aboriginal Affairs from 1967 to 1976 and of the Council for the Arts from 1967 to 1974. He was Chairman of the Royal Commission on Australian Government Administration (the Coombs Report) from 1974 to 1976. His publications include Other People's Money and The Fragile Pattern.

COOMBS - Science and Technology - for what Purpose?

There are two aspects of the title to this Workshop, and therefore of this paper, which interest me. First, the Workshop is a component of Australian preparations for the United Nations Conference on Science and Technology for Development - a title which presumes the answer to the question with which the Workshop is concerned. If the question in the Workshop title indicates the emergence among us of some doubts about the concept of development and the priorities which it implies, it may be the beginnings of wisdom. If, on the other hand, the question is a kind of 'Dorothy Dix', to which I am expected to reply in terms compatible with those priorities, it would indicate an unduly narrow conception of the purposes of the Workshop. I would hope to disappoint those who worded it and to suggest that there are fundamental questions to be posed and answered.

Second, the title links science and technology in a way which implies that they are directed to a single and common end. It is true that politicians, bureaucrats, businessmen and even many scientists tend to justify the activities of scientists, and their claim to a share of society's resources, in terms of the contribution which those activities have made and can, presumably, continue to make to technology and thereby to the outcome of industrial production in its widest sense. But this link is historically relatively new. Even the achievements of the industrial revolution and the technology which made them possible were the work of ingenious practical men rather than intellectually and academically equipped scientists. The forecasts of Bacon in the 17th century that the new approach to the study of nature would transform man's mastery over it, showed few signs of being fulfilled until this century. Until then, scientists were concerned to observe, to describe and to understand what man encounters when he confronts nature, rather than to answer the question, 'What must I do to achieve a desired result?' Accordingly, scientists' relationship with nature remained organic, indeed familial. Both nature and man were God's handiwork and even if man believed himself to occupy a special place - being made in the image of God and therefore the crowning glory of His creation - it was a place which carried obligations as well as privileges. Man was 'in charge of' the world of nature and this superiority, like other forms of nobility, carried the obligation of 'noblesse oblige'. It is only recently that scientists have generally rejected this relationship and have begun to see nature, and to act in relation to it, as an adversary to be conquered or a quarry to be exploited.

So science is not a homogeneous set of activities. There is science for understanding and science for manipulation. While they merge into one another, and the former frequently now provides the basis for the latter, their styles and motivation are different. Science for understanding is an expression of man's curiosity; his need to devise an intellectually graspable model of the natural world which enables him to find his way around in it; to think about it coherently and to realise how the things he observes 'hang together'. Emotionally the development of such intellectual models derives from the sense of wonder in the face of nature and has much in common with the creative work of artists. The tests by which the models are judged are concerned not only with their compatability with observed facts and their powers of prediction, but with their simplicity and elegance - tests which are essentially aesthetic. Indeed it may well be true that none of these models, even those most highly prized and most widely accepted by scientists, are compatible with all the known observed facts. The facts which do not fit tend to be pushed aside for later consideration or until their frequency compels the design of a new model into which more of them can be accomodated.

Science in this sense of the search for understanding does not, in my view, need to be justified by the greater power it confers on mankind. It is its own justification as a source of enlightenment and liberation; as a noble expression of the human spirit. A society which fails to give it opportunity and scope will be thereby the poorer. And a society which demands of its practitioners that they subordinate their imagination to the priorities of the accountant, the official and the military machine will destroy their creativeness as surely as if it imprisoned them in concentration camps.

This is not to suggest that science motivated by the desire to manipulate aspects of the world in which we live has nothing in common with science for understanding or that it does not have a legitimate place among man's activities. Rather, their purposes are different, the attitudes of mind of those who practise them may well conflict, and above all, science for manipulation must be justified by its results. It should be required to demonstrate that the benefits it confers on mankind outweigh the costs - material, social and spiritual.

I recall that in a paper entitled 'Science, Value and Meaning' delivered at a symposium in honour of Sir Macfarlane Burnet, Judith Wright, the wisest of Australian poets, saw this conflict not merely as that between scientists and literary artists but also as the expression of the internal conflict between the two sides of human nature. On the one hand the creative and the imaginative, which is shared by scientists, inventors and practitioners in the arts, and, on the other, the mechanic or materialistic, the manipulative, power-hungry side of us, which seizes on the achievements of science and transforms them into machinery for uses which scientists, as well as artists, often can't help but deplore.

I find this concept of a conflict within human beings rather than necessarily between them helpful. It acknowledges the complexity of human nature and the contribution which different and, indeed, opposing components of it can make to the richness of human experience. Even conflict is not without its place. Between such opposites in the world and in ourselves there is a tension which sharpens man's sensitivity, increases his self-awareness and stimulates his creative imagination. Ideally, the tension between the desire to understand and the urge to manipulate the world to man's advantage should be creative in this way. Above all, the concept suggests that human beings are capable, as whole personalities, of using that tension to reconcile the conflict.

If I understand Judith correctly, she is saying that the conflict has become one sided, that tension is being lost as the materialism of successful technology overwhelms the creative imagination in a kind of 'final solution' which involves a death sentence for what is best in the human spirit. She quotes from Professor Karl Jaspers:

> 'It is the Age of Technology, which seems to leave nothing standing of what man has acquired in the course of millennia in the way of methods of work, forms of life, modes of thought and symbols ... we today, misunderstanding ourselves, see ourselves in our technological ability as creators of salvation on earth without parallel - or we see ourselves as equally without parallel in our spiritual perplexity.'

Since those words were written the perplexities have multiplied and become more pervasive.

To judge whether the anxieties induced by these perplexities outweigh the benefits of the material salvation technology has made possible, it is necessary to consider the role and influence of technology in shaping not merely the product of our economic system, the achievements it has made possible and the costs which it has imposed, but also the effect of its methods on the institutional structure of our society, and on the life-style and values of those who compose it. Only then, as whole persons, can we pass a judgment which effectively involves the imaginative and the materialistic sides of our nature. By the term technology I mean the combination of 'know-how' and tools which man uses in his productive activities - a combination which has in recent decades been derived increasingly from the application of scientific knowledge. It covers, therefore, a range which comprehends at one extreme the Aboriginal's spear and his knowledge of the habitat and behaviour of the animal he hunts, and, at the other, the nuclear reactor and the knowledge necessary for its construction and for the safety procedures it demands. It is important to bear in mind that technology does not simply design tools - or create hardware - it brings an idea and a tool into creative association.

The power and significance of such combinations can be best illustrated by example. At certain critical stages in human history, technological developments, perhaps stimulated by the need to deal with population pressures or to respond to major environmental changes, have occurred which made necessary a revolution in the whole life-style of the peoples affected. Thus, the realisation that plants and animals could be domesticated and the yield of food increased by the use of primitive tools for cultivation brought with it the replacement of the hunter-gatherer with his seasonally controlled nomadic life by the shepherd and the gardener. We are inclined, long after the event, to think of this change as a step up in the material progress of mankind and as a source of a richer, more satisfying life.

In the long run, this seems to have been true, but in the early stages of the transition the opposite was more likely. The pressure of population on the food which could readily be hunted or gathered would have been urgent and immediate. The command over the new technology and its potential product would have been tentative and halting - the lessons difficult to learn and their promise uncertain. The story of the Fall of Man and his being cast out of the Garden of Eden to earn his bread by the sweat of his brow may well be a mythological version of that first technological revolution. It is a story which records man's nostalgia for the Golden Age in which God's natural garden was adequate for all his needs. Certainly Aboriginal Australians, who for tens of thousands of years had lived richly on the yield of that garden, now, despite their interest in selected aspects of the white man's technology, share that nostalgia.

Similarly, the first great fuel crisis was precipitated in the 17th century by the destruction by man of accessible forests in Britain, which made necessary the use of coal. In due course, this new fuel was to become a source of affluence and the foundation of British dominance of the world economy. But it was a long time before the potential of the fuel was even marginally realised, and for much of that time the need to use it was a deprivation and a hardship, particularly for the poor. Indeed, it was probably two hundred years before the benefits outweighed that deprivation at the lowest end of the social scale.

Much the same can be said of the wider industrial revolution, for which coal originally provided the power. The replacement of handicraft by mechanical tools in the textile and metal-working industries destroyed a way of life in which handicraft fitted into a largely self-sufficient garden and livestock/peasant agriculture. The closing of the commons made the peasant landholders into a landless proletariat dependent for income on work in the 'dark Satanic mills'. There can be little doubt that for generations the impact of that technological revolution was profoundly damaging to the health and welfare of the majority of working-class Englishmen. Indeed it may well have remained so had it not been that the opening of the 'new world' and access to wider markets brought cheaper food and placed the British workers in a privileged position from which they could demand a greater share in the affluence of their employers.

It was, however, this revolution which in due course achieved the most fundamental social change from which most of the characteristics of contemporary industrial societies are derived - the development of the conviction that it is by the possession and consumption of commodities purchased through the market that the quality of life can be improved. The application to production of the principle of division of labour and the breaking down of the activities into small separate uniform processes made possible great increases in efficiency. It enabled greater skill to be developed in the performance of individual processes, more effective tools to be designed, and advantage to be gained from the special qualities of the region in which production was carried out, from the special aptitudes of workers and from the ingenuity and energy of managers and entrepreneurs. All these factors contributed to economies of scale which encouraged the emergence of increasingly larger enterprises, the concentration of decision-making in fewer hands, the standardisation of products and the need for mass markets to demand and consume them. The result, over many decades, was the appearance of a great flood of commodities of enormous diversity and ingenuity, catering for human needs and fancies at prices with which the traditional crafts could not compete. The export of these commodities provided the resouces to buy cheaper food and exotic luxuries from the whole world - which also appeared as commodities to be purchased in the shops and markets of industrial society.

The prosperity which technological leadership, organising and trading skills brought to Britain, combined with the growing bargaining capacity of the workers, meant that the benefits of this revolution could be shared widely. The prosperity subsequently spread to Europe and America as these nations took over the principles of the division of labour and developed the technology which it had made possible. In these countries there is little doubt that the industrial commodity age has been felt to be, for the great majority, a period of fulfilment in which new and richer experiences and opportunities were opening up for those who composed that majority. Until relatively recently, these benefits could reasonably be seen as nett additions to human welfare, at least in the industrialised countries.

The newly available commodities and employment opportunities appeared to be marginal additions to a way of life which environmentally, socially and institutionally seemed largely unchanged by them. In the short run there seemed little reason to expect that these aspects of it would be significantly affected. Above all, experience, in due course, had come to suggest that the benefits of this rising production of commodities would gradually be shared by the poorer sections of the community (at least in industrialised countries) to an extent sufficient to ensure for them a steadily improving quality of life.

This expectation - combined with the much advertised confidence that science and technology could provide a limitless flow of new materials, new sources of power, new knowledge, processes and tools to keep the cornucopia of commodities overflowing - provided the apparent justification for the faith in industrial society: a vision of steadily increasing material prosperity filtering down to the poorest levels and spreading progessively into less industrially developed societies across the world.

But changes which are marginal in individual instances can, if widespread and continuing, transform a society and the way of life of its members. There can be no doubt that such changes have occurred in recent decades and that the pace of change has been accelerating. Many believe those changes are predominantly deleterious, and even those whose faith in the industrial society persists are more defensive and less confident in their advocacy of it.

Complaints that the rising tide of commodity production stimulated by science-based technology threatens to exhaust scarce and irreplaceable resources, that accumulating waste and damage to the environment are rendering it progressively less suitable as a habitat for man and indeed for all living creatures, are now familiar. We attach weight to these complaints according to the way in which we interpret the evidence and to the degree of faith we hold in the powers of technology. I do not wish to enter into that debate now, except for two remarks. Firstly, that all industrial, and most agricultural, processes use up more low entropy than is embodied in the finished product, leaving high entropy to be disposed of. Secondly, that while science-based technology may extend the life of natural resources, it does so predominantly by highly capital intensive, and therefore expensive, methods. Resources, even if they are not in danger of exhaustion, appear certain to become more costly. I will return to the economic and social implications of this at a later point.

In the meantime I wish to draw attention to some consequences of industrial production of commodities for human beings in their personal lives; consequences which flow from the way in which that production is organised and its impact on the institutions of human society.

Firstly, human beings are decreasingly necessary in industrial and agricultural production. To the extent that they remain necessary, they become increasingly appendages to the machines that perform the processes involved. Opportunities to use natural abilities, to exercise judgement and initiative or to make decisions become the privilege of the few. Even for them, it is a privilege which can be exercised only within parameters determined by the logic of the productive processes. Thus, for the great majority, work, which occupies the largest part of their waking hours, is an activity in which their most human capacities languish, with which they cannot identify and which provides neither security nor stimulus.

Secondly, as a result of the concentration of the population in cities, the separation of the work context from the home and the disappearance of social groups of manageable size, within which meaningful human relations develop easily and naturally, people are polarised from one another. Traditional institutions for social interaction and for the conduct of common affairs become ineffective.

Thirdly, the structure of the corporations which organise most production is essentially hierarchic. Power is concentrated in the hands of the few, accountable in only the most general and frequently the most ineffective ways, and then almost exclusively for the maintenance of profitability and the continuity and growth of the enterprise. Despite the absoluteness of this power, it tends to be exercised without personal responsibility, but rather vicariously and impersonally on behalf of the corporation - an entity without compassion to be moved or soul to be damned. It is no wonder that mining companies can behave towards Aborginal Australians as if they were no more than obstacles to the organization of production to be dealt with by the exercise of power.

Lewis Mumford, in his 'Pentagon of Power', points out that mining

> '... set the pattern for later modes of mechanisation by its callous disregard for human factors, by its indifference to the pollution and destruction of the neighbouring environment, by its concentration upon the physico-chemical process for obtaining the desired metal or fuel, and above all by its topographic and mental isolation from the organic world of the farmer and the craftsman and the spiritual world of the Church, the University and the City. In its destruction of the environment and its indifference to the risks to human life, mining closely resembles warfare.'

Mumford's words refer to the role of mining in the creation of industrial society. But much of the quotation would still be relevant to the policies of mining corporations, even though those who decide and speak for them would, in their private lives, be models of concern for mankind and his environment.

Fourthly, the growth of mammoth industrial corporations has brought into being a corresponding bureaucracy to serve, monitor, regulate and police their activities. As doubts increase about their environmental and social effects, the scale and intrusiveness of this bureaucracy is likely to grow more rapidly than its effectiveness and social responsibility. It is an easy transition for regulatory authorities to become the advocates and, indeed, the agents within the bureaucracy and the Government for those whom it is their function to control. A good illustration of the way in which public institutions are moulded to serve the purpose of productive corporations is given by the educational system, whose functions of providing the young with the intellectual tools for living have become predominanly the means to indoctrinate them with values appropriate to the functions and the welfare of those corporations. Thus Ivan Illich comments:

> '... schools ... teach people the accountant's view of the value of time, the bureaucrat's view of the value of promotion, the salesman's view of the value of increased consumption and the union leader's view of the purpose of work.'

Even more are these comments true of the unofficial instruments of education - radio, televison, the press and advertising.

The institutional corporation has provided the model for the institutions which conduct these and other public functions. They have been developed within and themselves embody the principles of a system based upon division of labour, specialisation of function and hierarchical authority structures. Each institution has its own purposes and powers appropriate to them. Those who make decisions within it are constrained to serve its purposes - the primary one being the continuity and power of the institution itself. Decisions, once made within one institution, become data for others. Despite the inter-relationship of these institutions and the fact that they, between them, are designed to serve society in all its purposes for the benefit of the men and women composing it, decisions are rarely, if ever, made by, so to speak, a whole man or woman but by a man or woman acting vicariously for a specialist institution within the limits of its purposes. Furthermore, those institutions will powerfully have moulded the values and ways of thought of those who manage and administer them. I think there is evidence that these institutions tend to turn people - both those within them and those affected by them - into accessories, concentrating power and decision-making capacity in the hands of those who identify themselves most absolutely with the institution, its bureaucracy and the values which are congenial to its purposes.

Finally, accelerating change destroys the balance between stability, change and tradition, undermining the basis of our institutions of law and political action. The relevance of shared memories, of traditions, of collective myths and of honoured precedents, to decisions and choices is destroyed. Political institutions, valid for the societies in which they developed, become meaningless in societies which bear little relationship to them. Thus, the practice and theory of democracy evolved in communities small enough for wide participation in discussion and decision-making to be a reality. There is little evidence of such participation in modern representative democracy. Indeed, our system has been more accurately described as one which gives the voter a choice between alternative (and occasionally alternating) tyrannies.

It is these effects of industrial society which have produced the scale and complexity of our institutions. So pervasive is their power that almost all significant decisions are made within them, constraining the scope for individual choice and initiative and destroying the opportunity for the natural tension between the creative and materialist aspects of human nature to be brought to bear on the decisions. It is because of their influences that the choices which we make, or which are made for us, seem invariably to come down on the side of the most materialistic and power-hungry of human aspirations - that 'the good that we would, we do not and the evil we would not, we do'. It is because our decisions are made not by whole men or women but by the agents of institutions of limited purpose that, although we know intellectually that every society needs both stability and change, tradition and innovation, justice and compassion, growth and decay, we reject the tension between them in favour of a 'final solution'.

The impact of these changes on the individual, the family, and other natural and traditional groupings is such as to impair the quality of the lives open to them. It makes ineffective the choice between conceivable life-styles. Above all, it destroys those ways of looking at the world to which men have turned to find meaning and purpose in life, leaving little or nothing but the hope of an increasing flow of commodities to replace them.

For many, even this hope may prove ephemeral. The belief that the productivity of the industrial system would, by the inherent processes of that system, be filtered down to be shared by the lowest strata of workers was based upon a few decades in the experience of Britain, the United States, and some western European countries. Even there, the benefits enjoyed were derived in part from the exploitation of the inhabitants of less industrialised countries whose resources and labour were obtained in exchanges weighted by monopoly power heavily in the interests of those already industrialised. Within these countries themselves, the circumstances had been unusually favourable. In the early stages of industrialisation, enterprises could be established without great capital, and with the opening of the New World natural resources were freely open for exploitation, while at home coal as a source of power appeared unlimited. Profits, the reward of the organiser of production, were good. The entrepreneur, as his capital accumulated, and economies of scale together with the technology at his command made possible falling unit costs of production, was in a good position to yield to the pressure of his, increasingly organised, workers for a larger share of the cake. Later, confidence in the burgeoning fecundity of science and technology in ensuring continued cheap materials and rising productivity seemed to justify the expectation that this state of affairs was inherent in our industrial system and could be counted on to continue.

However, in recent years radical changes have emerged. Some basic natural resources have become scarce - if not to the point of disappearance, then to the point where their proprietors can exact from the organisers of production a rent-like charge for their use. These proprietors now are like land-owners in Britain before the opening of the New World impaired their monopolistic position. They could exact from those who desired to use their land in production, a substantial part of any surplus in the product over what could be produced with the least productive land it would be worth while to use. The substantial increases in oil prices in recent years reflect the capacity of the proprietors of crude oil reserves to exact such a rent-like charge for their use. Such exactions are likely to become increasingly common and severe as resources become more scarce.

In addition, the need to pursue more remote and difficult sources of these materials requires more complex and costly technology and therefore greatly increased capital. As a result capital is in short supply and commands a price which, by historical standards, is high.

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The organiser of production is therefore confronted with demands from the owners of these two major factors in his processes for a greater share of his proceeds. This obviously affects both his capacity and his willingness to provide also an increasing share to those who supply the labour he employs or who supply him with materials and food which are produced from renewable resources. Indeed, if the extractions of proprietors of scarce material resources and of capital eat into his return so as to reduce them below his traditional expectations, he will feel compelled not merely to resist his wage-earners' demands but to try to reduce real wages. There is good reason to believe that the falling level of real wages during the last few years reflects just such a response by businessmen. Opinions differ about whether this check to the rise in wage earners' real income is temporary - a halt to enable an 'overhang' of earlier 'excessive increases' to be eliminated - or whether it reflects a continuing change in the distribution of the product of the economic system.

Those who are optimistic about the capacity of that system to continue to meet our expectation of a rising level of real income for even the poorest of our citizens pin their faith in the capacity of science and technology to enable the system to continue to deliver a growing volume of desired commodities. Whether one shares this optimism depends upon whether one shares the faith on which it is based. In the long run, there must be a physical limit to the production of material goods. It seems most improbable that we will not at some point reach the stage of diminishing returns from the application of knowledge to the means whereby it it achieved. But in the shorter run, the issue will probably be determined by the capacity of wage earners (employed and unemployed) to secure by negotiation, or by political or industrial action, a proportionate share of whatever increase in the total product technology makes possible. This will turn on the answers to the following questions. Firstly, who owns and controls the tools and techniques in which technology is embodied for productive purposes and by what processes are its benefits allocated? Secondly, is the bargaining power of wage earners sufficiently strong for them to negotiate their share of those benefits successfully?

Let us consider the second of these questions. There can be no doubt that in most industrialised countries, including Australia, the bargaining position of most wage earners has been seriously weakened in recent years. Firstly, the enterprises employing them face increasing charges for access to scarce resources and rising needs for increasingly expensive capital. If the return to the entrepreneur is to be sustained, it must, unless the benefits of new technology are rising correspondingly, be recovered from the share of labour. There is no other source and the entrepreneur's bargaining stance will be correspondingly tough. Secondly, the current pattern of technological change concentrates heavily on labour-saving developments, particularly from the application of computer technology. As a consequence, there is widespread and growing structural unemployment. Thirdly, the general state of the economy is depressed. This can be seen as the result of an unwillingness of businessmen to venture or expand until the level of return to them has been restored to that they consider adequate. Alternatively, businessmen may support policies directed to maintaining a sufficient level of unemployment to ensure acquiescence among wage earners generally to the reduction in their real wages.

Such acquiscence, even if it is achieved overall, will not be completely general. It is characteristic of labour-saving technology, particularly the most highly capitalised and sophisticated, that it becomes dependent upon the skills, or sometimes merely the presence, of a small number of operatives, the absence of which can immobilise the whole enterprise or even the whole commodity. Such operatives are, like the proprietors of scarce resources, in a monopoly position and therefore able to exact a significant share of the total product as the price of their services. However, proportionately, those in this fortunate position are a small minority.

Furthermore, the bargaining power of wage earners in the industrial countries is also being weakened by the internationalisation of the labour market. It is now frequently possible, especially for transnational corporations, to distribute the various phases of their production so as to take advantage of the most favourable labour conditions from their point of view, taking into account not merely special skills, aptitudes and experience but also the general level of wages and the aggressiveness of union leadership and organisation. This possibility will tend to equalise wage levels between countries. In current circumstances, equalisation seems more likely to be achieved by a reduction or slowing down of increases in wage rates in industrial countries rather than by a speeding up of increases in the less industrialised.

Let us consider now where the ownership and control of technology in fact lies, and how this affects the distribution of the total product. New science-based technology can emerge from the ingenuity of individuals, from research conducted in universities and similar public institutions, or from the organised research and development programs within existing firms. It can, through the patent laws, become the property of its developers, who can for a period make exclusive use of it, sell it to an enterprise, or allow its use by licence for an appropriate royalty fee. Patents lapse in due course and, in theory at least, the technology involved becomes freely available to all users. Much potential technology, the outcome of research in public institutions such as CSIRO and universities, is freely available to all.

But ownership of, or access to, technology - free or patented - is rarely enough in itself. To make use of it effectively requires always an understanding of how it fits into or can change existing technology; the 'know-how' to achieve such adaptation; and frequently, access to substantial capital and an organisation which can carry through the pilot-model stage, mount an expensive production program and advertise and sell the resulting product. Few innovators take their new technology through all these stages. Every university and research institute knows that its best chance of deriving reasonable reward from innovations is to share them with established commercial corporations. In the bargaining leading to such sharing, the weight of advantage leans heavily on the side of the potential user. He must commit large resources to developing and marketing the innovation, and he bears the risk of failure so that his share of the reward must be assessed accordingly. Those who produced the innovation lack the organisational resources to act independently. At best, they can only choose between a limited number of potential users. Yet this process ensures that most new technology becomes predominantly the property of existing, large, powerful corporations who will be able to extract a corresponding share of the extra product it makes possible. Even the provision that patents lapse, making their content freely available, does little to impair this monopoly advantage. The patent itself must be backed by 'know-how' and resources. Its corporation owner is in a strong position to ensure that by the time the patent itself has lapsed it is either succeeded by another patentable development or is protected by 'know-how', the development of which by others would be slow and expensive.

In over-simplified words, technology in our society is the property of large corporations. Like the ownership of scarce resources, it confers on its possessors the capacity to exact as a price for its use a rent-like tribute from the final product of the whole industrial process. It is therefore only the surplus over that tribute from the additional product made possible by technology which is available for the entrepreneur to bargain for division with the labour which he employs. In that bargaining, the wage earner (with some interesting exceptions), and even more the unemployed, have few, and anything but spendid, cards to play. Similarly, the poor countries cannot compete with the rich. In an equally weak position are those, many of them in less industrialised countries, who, primarily with their own labour and the renewable resources of the sun and the soil, produce foodstuffs and raw materials for sale to industrial corporations. They own nothing which is protected by monopoly - neither from scarcity nor from legal or economic strength. To them, the power of technology must seem a perpetual threat and the need to sell their product in the open markets of the world an invitation to a game in which all the aces are in the other hands.

We have, I believe, been misled by our experience with the economic system in industrialised countries over the last 150 years. Its success in producing a flood of commodities and possessions, in which even the poorest seem to have shared, has been due largely to circumstances clearly temporary: to the running down of our capital in exhaustible resources; to the fact that we ignore the accumulating costs of pollution and other environmental damage; to our exploitation of the populations of non-industrialised societies; and to the continued existence within our own communities of women and other minorities whose unpaid work has made the division of labour in market-oriented enterprises socially possible.

We may, perhaps, cheerfully dismiss the doom-sayers like the Club of Rome, who foresee early physical exhaustion of the world's resources. But we cannot ignore the prospect that private and corporate ownership of property in land, scarce resources, technology and know-how, as well as in rare skills and capacities, will lead to increasing concentrations of wealth, income and power, balanced by increasing poverty at the other end of the socio-economic scale. The extreme end of that scale may be in other countries, in other societies, but it will be among men and women, and our own society will not be wholly immune.

In politically mature societies, it is perhaps not inevitable that polarisation of affluence and poverty should develop as absolutely as I have described. John Stuart Mill, more than a hundred years ago, in considering the implications of private ownership of the increasingly scarce agricultural land in England, recognised that as a consequence of that scarcity, land-owners were placed in a monopolistic position and able to exact rent as the price of access to their land. He remarked that this monopoly could not be prevented, but that it was possible that the rent from it could be held in trust for the benefit of the community. The relevance of his comments was apparently dissipated as the opening up of new lands, and later science and technology, pushed the prospect of scarcity in land into the background. That relevance has now re-emerged dramatically, along with increasing scarcities of other natural resources. It is not beyond the wit of man to channel some part of these rent-like exactions so that they can be held in trust for the community's benefit. If we fail to achieve this, technology and science so far as it is linked with it, will become exclusively the handmaidens of the rich and powerful.

It is strange that, just when we are coming to doubt the validity of the faith in the division of labour and the power of technology, we are urging this combination so forcefully upon the poorer, less industrialised countries of the world. If we, with nearly two hundred years of experience, find the impact of technological change more than our society can adapt to, how much more destructive must such a change be in societies whose pattern of life, social processes, and view of the world are tied so irrevocably to the past!

Every technological development poses, for the society into which it is introduced, a learning process, requiring not merely new skills and patterns of behaviour but often also radical changes of institutions and beliefs. It is a fundamental principle of pedagogy that one must move step by step from the known to the unknown. Jean Jacques Rousseau, perhaps the most sensitive of educational theorists, expressed this idea in its most absolute form when he said that one cannot teach what is already in the mind of the learner. No technological change can therefore be comprehended and absorbed into the life-style and institutions of a society where the roots on which it must grow do not already exist. Attempts to go faster than this will do more damage than good - certainly in the short run and perhaps for generations or even for centuries.

Should we not therefore, in purporting to help those of the Third World, acknowledge in due humility that the limit of technological change which can benefit those now living is that which can be comprehended within, and is compatible with, their present life-style without radical change in institutions or beliefs.

Of course, more than this is acceptable if we apply the measure of the gross national product or if we see the greater affluence of the elite in these countries as an adequate compensation for the impoverishment of the already poor. What reason have we to believe that technological change in these countries will not be marked by the polarisation of affluence and poverty which, without doubt in its early decades, it produced in our own society?

But in justice, it is not for us to decide. Let us stand ready to provide the ideas and the tools which the people of these lands - as persons, as producers, and as communities - want to enable them to do better what they now do, to preserve their independence and to modify their way of life only as they would themselves desire - making sure that the choices are in fact those of the men and women directly concerned.

Thus it has been said:

> 'A country will achieve self-reliant or autonomous development to the extent that it acquires and expands its own technological base ... consciously choosing those fields in which the process can grow roots ... the indigenous technological tradition should not be discarded.'

However, even if the distributional failures of the industrial society were moderated, there would remain the more human problems to which I have referred earlier: the emptiness of that part of life concerned with work; the polarisation of people from one another; the concentration of authority and power in the hands of the few; the spreading bureaucracies; the destruction of traditional values and the breakdown of the balance between stability, tradition and change; all of which have combined to render our society increasingly without cohesion or sense of purpose.

It is necessary, I believe, to call in question the basic assumptions on which industrial society rests - that increasing quantities of commodities of themselves add to human welfare, that the indirect costs of the division of labour, specialisation and the domination of human affairs by the market can safely be ignored. There is good reason for that questioning. Any serious consideration of the factors which contribute to the quality of human life indicates that psychic income, the response of the whole human person to his continuing experience, derives from many factors which form no part of either his money income or the commodities he can purchase with it.

The first conclusion, therefore, about the purposes of technology is that the question posed in this Workshop should be rephrased to read 'Science and Technology - for Whom?' We must, in any reconsideration of their role, recognise that the final product of our economic and social system is people, and consequently that the role of science and technology should be to ensure to those people the best possible quality of life.

Essentially this life consists of a succession of activities performed in their related physical and social contexts. The degree to which those activities yield not merely survival but physical and psychic health and joy in living will depend on the nature and quality of those contexts; on the personal relationships which are established within them; and on the degree to which the activities and contexts yield a reasonable balance between privacy and a sense of belonging, between security and challenge, and between man's own personal achievement and its compatability with whatever faith he may hold about the purpose and justification of life.

It is possible to identify such factors upon which the quality of life depends and to assess with usable accuracy the scope for them which any society offers its citizens. It is therefore possible to assess the impact which any technological changes will have - not merely on the quantity and quality of commodities available to members of the community but upon the whole life-style as expressed in the combinations of activities and contexts it offers it citizens. This assessment can be made only by 'whole' men and women, not by those who are the instruments or the accessories of institutions of limited purpose.

Such an assessment now leads, I believe, to an inevitable conclusion that industrial society increasingly denies many of its citizens the opportunity to choose and make effective a life-style in which those combinations of activities within contexts add up to physical and psychic health and joy of living. This result has emerged because the consequences of the dominant concept of division of labour backed by science and technology, other than those which are reflected in the output of commodities, have been largely ignored or accepted as inevitable. Those ignored consequences have led inexorably to threats to the environment, to increasing scarcities of basic resources, to concentrations of wealth, income and power and to unmanageable giantism in the social structure.

It is not necessary that science and technology should serve such purposes. Already, increasing numbers of those concerned are turning their attention to considering some of the more obvious side-effects of the concentration on commodities. There are serious efforts to reduce waste, to economise on capital, to extend the lives of durable goods, to recycle materials and so on. But these deal with symptoms rather than disease.

It is necessary also to ask whether the dominance of the market need be accepted; whether the principle of the division of labour and specialisation is valid for all aspects of our lives; and whether we must acquiesce in the growing concentrations of power which, from our experience, we know will be abused.

In historical periods leading up to dramatic or revolutionary change, it is possible after the event to discern precursors which foreshadow the pattern of that change. These precursors are much less easy to recognise before or even during the process of change itself. But I wonder whether it may not be significant that growing numbers of people are seeking voluntarily to form groups small enough for those within them to care for and help each other, for self-reliance of individual and of groups to be more significant, for producer and consumer to be more often the same person. In other words, that increasing numbers seek to escape, in part at least, from the tyranny of the division of labour and from the complexities and polarisation it ultimately leads to. It may be in the kibbutzim of Israel, in the communes of China and the varied voluntary groups emerging in the Western world that the pattern of the future can be seen. Some of the groups may be composed of impractical visionaries, but their questions may be valid - even if their answers are imperfect.

If I am right that it is in such smaller groups, communities, and societies that a healthful future for mankind will be found, the challenge to science and technology will be to devise a combination of ideas and tools for it - a technology for persons rather than for institutions; a technology which ensures that a man's right to choose is not overborne by the machine or by the institutions which serve its purpose; which optimises not production but the whole quality of life. When scientists and technologists judge their own performance by these tests, the tension between the creative and materialist sides of man's nature will be restored.

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DISCUSSION

Question:

At the beginning of your lecture you were saying, in essence, that science is a creative activity which could be destroyed essentially by trying to come to terms with defence or industry or other purposes. It seemed that you were suggesting that basic science and applied science really had to go their separate ways. You then seemed to suggest the opposite of that, that in fact science which has to come to grips with real problems can be a very genuinely creative enterprise. I am not quite sure where you left us - the possibility of the latter as an ideal which isn't realised often enough, or whether in fact the dangers of selling out to an easier solution to practical problems may be so great that you feel that a true marriage of creative science with practical purpose isn't really possible. I believe that this is quite an important question in relation to the things we are going to be discussing and I would like some clarification.

Coombs:

The point that I was trying to make was that, in its creative aspect, science does not need the justification of being able to point to results which are materialistically favourable. It is an activity which, like the arts, is part of the graces of life. It is its own justification by the quality which it presents because it does embody and express, at a very high level, capacities and qualities of the human mind which are unique and splendid. So that, even if we decided that science should not be applied and used for material purposes, that would not mean that there should be no science. But I did not intend to say, or even to imply, that that kind of science could not lead on to what I call 'science for manipulation' - science for modifying the world as we see it. I did not intend to suggest that that kind of science had no place, but I did say that it has to justify itself by its results. I went on to try to examine the present balance in the justification of science as applied to technology, to look at the benefits on one hand, and the cost and burdens on the other. I believe it is an assessment which does need to be made and not simply in terms of output of physical goods but of the impact of the whole life-style of people. I believe that science and technology is still capable of adding greatly to the quality of human life and ameliorating a lot of the hardships which men and women face in the world. But I believe for it to do that adequately it needs to reconsider its objectives, to reorient to some degree its directions, and, particularly, to examine its impact upon the human and social aspects of society.

Question:

May I take up your challenge, at least I think it is a challenge, in your statement that mining is really an act of warfare. It is a fine thought, but without mining you have no road metal, no cement, no bricks, no mortar, no steel - none of the materials that make our present lives possible - none of the facilities that give to me and my family shelter from the elements. Do you conceive of a non-warfare type of mining? Do you believe that mining can be a human, personal-oriented type of activity? What kind of mining might be possible which is not in the category of a warfare situation?

Coombs:

I agree that there is a fundamental problem here and that to some extent there will remain elements of warfare in mining, however humane or in whatever civilised fashion it may be conducted. But I believe there are differences - there are degrees in the way in which mining is conducted. I think the mining industry is a very good example of an industry with very limited direct objectives. It is organised to achieve those objectives and gives, in my view, too little consideration to the other implications of what it is doing. Now that is not necessarily so. I remember I had a good deal to do many years ago with a very distinguished member of the mining industry, Mr W.S. Robinson. Let me tell the story, because I think it illustrates the kind of thing I mean.

When I was going to Broken Hill - consider the kind of hell-hole that was this hotbed of communism, wickedness and sin - it was a very uncomfortable place. There were almost invariably strikes last week, this week, or next week. There was a very considerable degree of bitterness and hatred in the whole relationship between the people who worked in the mine and the companies for whom they worked. W.S. Robinson was not a great financial owner, but he was a very influential person in the mining companies. He went to have a look at the place and reached the conclusion that the trouble in Broken Hill

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was the result of the failure of the mining companies to consider the human problems of the people who lived there and worked in the mines. He made effective cooperation between the unions whose members worked in Broken Hill and the management of the mines. Over a very short period of years the whole atmosphere of Broken Hill was transformed and that aspect of its life, which was universally accepted as inevitable in those times, has not been heard of in years. I'm not saying it is a perfect place by any means, but it was transformed by the attitude of a man who was a mining man who realised that the product of mines is not only metal, it is also people.

Question:

Is it not a fundamental dilemma that science which is undertaken to promote understanding, inevitably and unforeseeably leads to 'science for manipulation'?

Coombs:

Perhaps not inevitably, but certainly with a high degree of probability. Again, I don't feel that that is necessarily bad because it is - for whom do you manipulate? With what objectives do you manipulate? I believe (that those engaged in) science and technology have allowed themselves to be corrupted. I don't mean financially, but to concentrate on solving the problems which are mechanical, materialist. They should also consider the impact of what they do and devote some of their energies to producing ideas and tools for people as well as for production.

Question:

You have spoken very effectively about the 'whole man' and the 'whole woman' and the prospects of the life that they lead. You have also spoken of bureaucracies and of how people are divided in their roles in life. I'd like to know if you are as pessimistic as I judged you must be in assessing the influence of whole women in the political processes of science and technology?

Coombs:

Yes, I am pretty pessimistic, but I sometimes find it hard to judge whether that pessimism is a reflection of my age rather than the realities of the position. There are moments when I meet younger people when I feel that the pessimism is unjustified. Also, I believe there are signs - they are not bold or striking signs as yet - but I believe that the move towards the establishment of small operating groups is one. When I was writing a report on Australian Government Administration I read a book which talked about the influence of scale on institutions. It came to the conclusion that if you have to run a big enterprise or a big institution, the right way to run it is as if it were a group of small ones. I believe that approach may be a kind of transition from our present 'giantism', as I have called it, to a new pattern of smaller functional operating units. At the moment I believe the influence of most people on the political social processes is substantially negligible. I don't think that is inevitable, but I cannot say I am bursting with optimism.

Question:

As one of the few educators here, I would like to challenge your treatment of education in the process. I take the point that education has to be a gradual process in a community. But is it really true that our schools turn out a lot of gross materialistically minded people as capitalist fodder? We turn out a great number of monks and nuns and priests and clergy of various kinds. We turn out a very great number of school teachers, who unfortunately seem to be very unworldly people. We even turn out university academics, who often too are unworldly, and civil servants of various kinds. I think the bit about education was quite unnecessary to your thesis, as the other forces you describe are quite strong enough to produce the results you described. You yourself have been heavily involved in education over the years - do you really think you were serving the capitalist system?

Coombs:

Well, it is true that I exaggerated that point, in the sense that I made it seem as if it was universally applicable instead of being what I believe to be a significant element in the way in which the system does in fact operate. It is, of course, exceedingly difficult for anybody to teach any kind of skill without conveying an attitude towards the world. In learning a language, you learn a substantial part of the culture. When you learn your own language you acquire a great deal of the culture of your own people. But I still think I am right in saying that our educational system is increasingly yielding to pressure to subordinate its task of giving people the tools to live with, to producing what you called 'capitalist fodder'. There is pressure all the time on the educational system to produce the kind of person who fits into the contemporary economic and social scene. I accept your criticism that I overstated this point and I accept also that the educational system does in fact turn out a wide diversity of people, many of them of high idealistic quality. But to some degree, of course, this indoctrination is unconscious - it certainly isn't conscious on the part of the people who conduct it. But the educational system cannot fail to reflect the prevailing values and attitudes of society. Inevitably it is going to pay particular attention to the attidues of those people who are powerful and who are in significant decision-making positions.

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Question:

I'd like to ask Dr Coombs to comment on two questions which interest me. The first is what I might call the Malthusian problem, that population is really limited by the misery of the individual. In medieval times one might say life was nasty, British and short. We have had a transition, thanks to technology, to a situation where we have had an enormous increase in population limited again by the balance of misery. One might ascribe to technology the enormous increase in misery - numbers of people multiplied by average misery - which we have, and although we may not have reached equilibrium yet, it certainly is coming. The Malthusian problem is, I think, as relevant as the Millsian one to which you referred, but you haven't commented on that question.

The other question is the problem of the integrity of the developing nations. We seem to be carrying a 'white man's' burden here to some degree determining what the developing nations need and should have, whereas, in fact, the demand for technology from developing nations is the driving force in the transfer. I don't think the developed nations are driving the transfer. To a great extent the developing nations are motivating this transfer and are determining the sort of goods which they buy.

Two questions then: are we not producing people as well as consumables, and what do we do about the integrity of developing nations in the statement of their needs in our terms?

Coombs:

I agree that the Malthusian problem has definitely caught up with us and the issues proposed by him are abundantly clear today. I suppose technology is making a contribution to solving this problem, but it is very relevant, I think, to the kind of approach we make. The growth of population certainly sets a limit to the downward spread of affluence to which I referred. I would accept that as a valid point and one to which I could have devoted some time. Perhaps I passed over it, like most of the environmental ones, as an issue on which most people these days are familiar. I tried to concentrate on the social and institutional aspects of the situation, to which too little attention is given to the statement of the problem, let alone to its solution.

It is true that the demand for access to Western technology comes very strongly from the so-called less-developed countries. It comes, of course, predominantly from the elite in those countries - the property elite and the administrative and governmental elite - and much less so from the producers and the communities. Some of those demands are made in good faith, because the people who make them share the expectations which we ourselves have built up about the prospective results of technology. I said that it is a matter for them to decide what they need, but perhaps they could be given a little more objective or balanced information about the probable consequences of the alternative choices.

Part of what I had to say was an attempt to draw your attention to the fact that our society is not a homogeneous group and that the changes coming from the application of technology are very uneven in their incidence and that the unevenness may very well be growing. Even more so is this true of the less developed countries, where the spread of incomes and of affluence is, if you can exclude a very small proportion of the multi-nationals, perhaps even greater in the social sense than it is in our own. It was because I was anxious to emphasise that the immediate impact of significant technological change on an existing pattern of production in underdeveloped countries is almost certain to damage, rather than to help, those actually engaged in that form of production. In other words, nations are not homogeneous, they are groupings of people in social patterns, and the impact of any change cannot be assumed to be uniform between those groups. Indeed, the opposite is almost certainly true. The impact will differ from group to group and some will benefit and some will lose. Any assessment, therefore, of the impact of technology should attempt to answer the question 'who benefits', as well as, 'how much?'

Question:

It has been a most provocative address and Dr Coombs has opened up a number of issues. I am a little troubled by his use of the word 'manipulation'. 'Science for manipulation' was the phrase, and I am wondering if he is talking about manipulation of things, in other words the application of science, or is he talking more about the manipulation of people by science and technology. If the latter, I'm a little less comfortable and I would appreciate a clarification of the use of the word.

Coombs:

When I used the phrase 'science for manipulation', I meant science used for bringing about changes in the state of nature as it existed at that point. It was manipulation of things, manipulation of the physical world. I did go on to draw attention to the fact that manipulation of things and of the natural world cannot be presumed to have no impact on people.

Question:

The measure of quality of life in a country is often taken to be the average annual income per head. This seems to me to be wrong, since it does not indicate either the distribution of the income or what it is used for. Is it possible to set up some index of 'quality of life' which is not necessarily equated with material goods, but rather with opportunities for happiness? This seems to be the critical question in our context, because it would set up a reasonable objective for development to aim at.

Coombs:

I agree that gross national product is no significant indicator of the quality of life. Indeed, I did remark that the output of the system, finally, is people. In a very real way the gross national product is not the product of the system, it is the cost. That is, what we have had to put in, what material resources we have had to use up, what human labour has been devoted to the process in order to produce the kind of people that, in fact, come out. If you look, as I have had the opportunity to do over recent years, at primitive societies, it is clear that it is possible to lead a life which is not merely providing survival but a physical and psychic income of real joy of life. I believe the concepts are different. I don't believe that the problem of measurement is as intractable as economists are inclined to believe. It is true that you will have great difficulty in measuring it (quality of life) in terms of dollars and cents, but I believe that it is possible to establish a set of criteria, and perhaps to indicate in an ordinal fashion, if not in an absolute fashion, the kind of performance which is provided by particular societies. Comparison between one society and another, however, is very difficult, but so it is if you are measuring gross national products, because the figures will mean something quite different from one country to another. A level of poverty in the United States would be incredible affluence in Bangladesh. The fact that it is difficult I don't believe rules out the establishment of criteria which could be some guide to policy makers and to developments.

Question:

Dr Coombs has painted a gloomy picture of our society, with which I agree. I think that we do need to change our aims. I would like to take you back, Dr Coombs, to your statement that any change in another country might be for the worse. How would you deal with the question of hunger in those countries? I would like to hear your views.

Coombs:

I believe the places where the best progress is made are the ones which are not receiving any help. In very many places, the help does more damage than it does good. I'm not quite sure how far policy can be guided by the conviction that if you see people starving you must do something to prevent it. In a personal, human sense that is obviously true, but we should not imagine that we are doing anything significant or permanent or actually making any changes at all. Fundamental changes are not the results of that kind of help. People will still starve, but they may be different ones. We could, of course, be slightly less monopolistic so that they receive somewhat more for the products that they produce and pay somewhat less for the ones that we produce. Also, of course, I believe it is possible to improve their capacity for independence, provided you can find ways of doing it which don't impair their independence and take decisions out of their hands - which is what, I fear, is usually happening. I agree that this is an appallingly difficult problem. In a personal sense, it is hard to reconcile with your conscience the continued existence of obvious poverty. But we have to think more about passing from that to the conclusion that anything that you do which avoids that poverty temporarily is necessarily good. The only comment I would offer is that I believe the fundamental principle is that what is done should be done by them, by their decision and in their own way.

Question:

I wonder what might be learned from developing countries, something of their attitudes towards life. This was brought home to me many years ago when in our formulae for maximising production we maximised economic return. I can still hear the wonder in the students of that time; what they wanted was not a maximum return for the man growing the sheep but more wool to put on the backs of the people.

Coombs:

If I may say so, that was possible for them because that was the pattern for their lives. They were not producing for the market, they were producing to use. I believe that that is part of the process to enable them to sustain a pattern of life which is not geared to the way ours is.

Question:

I would like to go back to where you said that the pressures for technology and development were usually coming from an elite. I would like to put it to you that the need for technology in the lesser developed countries is not to make great profits for particular investors or entrepreneurs but to find the means to have an excess of capability in order to spend it on resolving the hunger problem, reducing infant mortality by say a factor of nine or so, and producing a liquid society with cultural values to which they aspire. So the proposition really is, what sort of technology do they need in order to acquire this uncommitted component of the national product, not as a debt but as something to spend on schools, hospitals, child care and the like. Isn't this the sort of technology which ought to go there? Isn't this the sort of thing we ought to be looking for, rather than trying to keep the happy primitive state which you have been suggesting to us?

Coombs:

I am not advocating a primitive sort of life as something which we should preserve or something which we should impose. What I am trying to emphasise is that I believe the choices should be made by the people on the spot, in the pattern of their own way of life. If technologists went and lived amongst the people for whom they were going to design technology, and evolved the technology on that spot in response to their requests, or to offer to them, it could be that the technology could serve the purposes of that group. You have gone on to refer to the possible purposes which they might want. I think those purposes, the ones you have described, exist in some hospitals and schools in a literate rather than an oral society or oral culture. All these things are part of our society and are part of the things we value. They may be some of the things which the primitive societies value but, in my experience, not always so. Certainly, the things that happen to most of the hospitals and schools that are built, at great expense, in Aboriginal communities don't suggest that they value them too highly.

Certainly there are moments that I doubt the superiority of a literate society over the oral ones. Max Davies told me about an Aboriginal who had given him from his oral tradition an account of an event of climatic change in North Queensland which he said occurred 8000 years ago. In an oral society it was, in a sense, a record of that event. Now, there is no literate society which has a record of events of 8000 years ago. So the literate societies are not necessarily in all respects superior to non-literate or oral societies.

I just make that comment in passing to suggest that it really isn't for us to presume what these people want or should have. What we should be seeking are the ways in which we can put technological services (I don't mean the technology, I mean the purposes, the qualities and capacities of the people) at their disposal for their purposes and their people. Then perhaps we might be making progress.

Question:

Dr Coombs has challenged us to think in terms not only of the right people making the decisions in terms of the need to provide assistance outside our own environment, but that within our own community we should have the right kinds of people making those decisions too. He has called them 'whole people', and I must say I am very attracted to the term. In my own mind, that means a person who is somehow able to encompass, in an appropriate way, a balance between the creative and material. I wonder whether he has any words of wisdom as to how to promote the multiplication of that particular kind of person within their own community and the larger community they serve.

Coombs:

I am glad you liked the phrase, but I am afraid you have used it in a different sense from me. When I used the term 'a whole person', I was contrasting that person with a person who acted as an instrument of an institution or organisation. I am not suggesting that we need people of superior quality. I am suggesting that we need people who will not be committed to a point of view before they start to consider the problem. If you work for a government department you consider problems as a member of that department. If you are a member of the Police Force, you consider crime, or the attitude of particular people in the community, as a member of the Police Force. If you are asked for an opinion it is almost certain that the view you express will be a view determined by the institution which you serve. I believe that ordinary people are capable of making an uncommitted judgment if they are removed from the context which is determining their attitudes, moulding their values and their opinions. I think that people are capable, given the right procedures in the right contexts, of removing themselves from the situation of being a mouthpiece for an institution. But it does call for a change in procedures and a shift in the context of which the decision is made. The essence of what I am saying is that most decisions are made in institutions by people who speak, not for themselves, but for that institution.

THEME 1

THE CHANGING ALLOCATION OF RESOURCES OF SCIENCE AND TECHNOLOGY IN AUSTRALIA

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INTRODUCTION

The great paradox of Australian science is that though Governments provide most money for its support, until very recently there has been no great political interest in science and only minimal interaction between science and politics. This situation is beginning to change and Leon Peres identifies some forces pushing science across the political threshhold. One of those factors is the development of a concern and an apparatus for 'science policy', which is itself an important component of science-politics interaction. Leon Peres does not discuss recent developments in this field in any detail because a number of such reviews have been published in the past few years. The most recent of these, which provide a useful context for the discussion of the politics of Australian science, are those by Professor J.A. Ronayne and Dr C.L. Rubinstein.

Peres' paper is in four parts:

- the period of apolitical stability of Australian science - from the beginning until the early 1970s;
- the period of changing politics - from the early 1970s and continuing;
- likely future developments; and
- Australian lessons for underdeveloped countries.

The evolution of Australia's major scientific institutions lies at the base of Australian science policy. In the late 1970s, the Federal Government embarked on an interpretative scrutiny of a number of these institutions, and others, most notably the Defence Science and Technology Organisation, require similar critical evaluation. These examinations raise large questions about the ongoing and future allocation of our research and development (R&D) effort and the problems of institutional overlap, balance and flexibility. Ann Moyal considers CSIRO, the Australian Atomic Energy Commission, and the Defence Science and Technology Organisation. She examines the need for some coordinating overview mechanism for our science institutions, and for closer interrelationships and mobility between government research bodies, universities and industry.

Professor Badger's paper is primarily concerned with the role of the Commonwealth Government in Australian science and technology, as the Government provides over 60% of the country's total expenditure on research and development. The major government research agencies and other forms of government support for R&D, and trends in R&D activity over the past decade, are described briefly.

THEME 1 - Introduction

In many countries, increasing use is being made of scientific knowledge in formulating government policies, and in Australia this has been reflected in the recent establishment of the Australian Science and Technology Council (ASTEC). The Council's functions, activities and mode of operation are described.

In order to set the background from which coordinated policies can be developed in the future, ASTEC has completed a broad-scale review of science and technology in Australia, and this is one way in which the Council is able, on its own initiative, to identify and offer advice on problem areas requiring Government action. A second mechanism applies when the Prime Minister wishes to seek the advice of ASTEC on a specific matter, and a third method by which the Council functions is advising the Prime Minister on initiatives in science and technology brought forward by government departments.

The latter part of Professor Badger's paper is devoted to consideration of the present situation and problems in the allocation of resources to science and the technology. Particular attention is given to the need to support industrial R&D and innovation in manufacturing, and to mechanisms for the provision of major national scientific facilities.

The discussions ranged over a number of aspects of the allocation of scientific and technological resources. Politics and interpretation of national needs have a strong influence on the structure and broad emphases of scientific research in Australia, though until recently there has been only relatively indirect influence on program content. The syndicate felt that, on the grounds of both experience and realism, there is no need for scientific establishments to be excessively shielded from political pressures, though limitations on the form of influence need to be recognised. Particular institutional models are not appropriate for transposition unaltered from one country to another. Further, models for decision-making and allocative systems need to be carefully tailored to the particular structure, resources and needs of a country.

The syndicate found that sectoral funding, and elaborate advisory structures, constituted an effective allocative mechanism for an industrialised country like Australia, but that such a mechanism would be of limited value to developed countries. However, developing countries could learn a useful lesson from Australia's experience of the causes and effects of institutional rigidity. Likewise, developing countries should not be misled into equating excellence only with pure research, and should link the research directions in universities to areas of national need. Finally, the syndicate found that a well-developed infrastructure was needed before the advantages of a wider public involvement in scientific and technological issues could be obtained.

THE CHANGING POLITICS OF AUSTRALIAN SCIENCE

BY

LEON PERES

Leon Peres is Reader in Political Science, University of Melbourne. He has contributed extensively to Australian science policy studies, to analyses of science policy arrangements in a number of South East Asian countries and to the general literature on Australian Public Administration. He was a member of the Science Task Force of the Royal Commission on Australian Government Administration 1975/76, and has been a member of the Australian Science and Technology Council since the permanent establishment of that body in April, 1977. He is currently President, Victorian Regional Group, Royal Institute of Public Administration.

INTRODUCTION

The great paradox of Australian science is that though Governments provide most money for its support, until now there has been no great political interest in science and only minimal interaction between science and politics. This situation is beginning to change and the paper identifies some forces pushing science across the political threshhold. One of those factors is the development of a concern and an apparatus for 'science policy', which is itself an important component of science-politics interaction. This paper does not discuss recent developments in this field in any detail because a number of such reviews have been published in the past few years. The most recent of these, which provide a useful context for the discussion of the politics of Australian science, are those by Professor J.A. Ronayne[1] and Dr C.L. Rubinstein.[2]

This paper is in four parts:

. the period of apolitical stability of Australian science - from the beginning until the early 1970s;

. the period of changing politics - from the early 1970s and continuing;

. likely future developments; and

. Australian lessons for underdeveloped countries.

1. THE PERIOD OF APOLITICAL STABILITY

Australia's response to the research revolution of the early twentieth century was to incorporate science into government bureaucracy. A good part of Australian science is still there and an even larger part directly dependent on government support. The latest published figures[3] show that, in 1973/74, Governments provided two-thirds of all funds supporting Australian research and development, and about two-thirds of that money was spent on 'in-house' research. That is, government laboratories performed about 42 per cent of the nation's research as measured by money and 40 per cent of the national manpower effort was expended in government laboratories. The remaining third of the funds was said to be provided by the private sector, which performed about the same proportion of the national R&D effort but utilised only 25 per cent of the manpower effort. The higher education sector was the junior partner in R&D performance; its funds were provided overwhelmingly by Governments - 22 per cent of the national figure - but 32 per cent of the manpower effort was located in the universities.

Although the latest data are not yet available, there are indications that in the business enterprise sector figures for both expenditure and manpower have dropped markedly, perhaps by one-half overall and in some cases by 60 per cent.[4] Even if there were no doubts about the 1973/74 figures, these recent declines in private industry expenditures and manpower efforts probably reinstate 'Governments' to the even more dominant position occupied in 1968/69 when they provided 75 per cent of the money and performed 55 per cent of the national R&D effort. The great spenders and performers were, and are still, CSIRO and what is now the Defence Science and Technology Organisation (DSTO) in the Federal Government, and the various agricultural departments in the States.

There are, of course, a number of questions that can be raised about the official figures, but they are probably suggestive of the 'right' proportions. They do not, however, say very much about allocation decisions except at the very gross sectoral performance level. It is difficult to judge changing allocations as between kinds of research, fields of science, programs, problems tackled, or even the objectives to which our national research and development effort is said to be directed. The obstacles in the way of reaching clear-cut conclusions about changing allocations from the published figures are enormous. Quite apart from doubts often expressed about the figures themselves, there are the warnings included throughout the official publications that the finer the categories the less reliable the comparisons.

Despite the doubts, there seem to be three fairly firm facts about Australia's scientific establishment. First, the percentage of Gross National Product (GNP) devoted to R&D reached the 1 per cent level in the early 1960s and has since stabilised at 1 to 1.2 per cent. Next, the three main performance sectors share the national R&D effort in much the same way now as they did 10 years ago. Finally, government funds go predominantly to government performance, but with a share to the universities. Until now, industry has received hardly a cent from Governments, whether by way of grant, contract or special taxation concession. So much was known in the mid-1960s and the elaborate apparatus of Project Score has done no more than confirm those facts.

The impossibility of assessing changing allocations may be no more than a reflection of the fact that allocation decisions have not been among the burning issues of Australian science politics. To be sure, the universities and industry have advocated enhanced research performance roles for themselves - at government expense. Until recently, however, advocacy has not been for the reallocation away from government but for increases in government expenditure. Governments responded, at least in relation to the universities, beginning about the late 1950s, but hardly at all with respect to industry. The great allocation principle from about the end of the Second World War was an incremental one. Allocations to existing bodies increased at a slightly faster rate than the rate of growth in GNP with an occasional spurt, as for universities, until stability was reached in the mid-1960s.

The growth of science in Australian industry has been due almost exclusively to industry's own efforts. It is, however, interesting to speculate whether a similar incremental principle applied also in industry, and whether the growth rate in earlier years was simply a function of prosperity and some benign satisfaction that flows from the presence of a research division or a research centre in the company. The rapidity and scale of industry's cut-back on research in recent years raises the possibility that industry has no great commitment to research through thick and thin. My impression is that, anyway, most of the advocacy for greater government funding of research in industry has come from scientists in industry and rarely from the captains of industry. The justifying arguments have been that in other countries the relationships between the performance sectors are the reverse of the Australian, though Governments still provide most of the money, and that other Governments prefer industry (and the universities) to perform the research that Governments feel ought to be performed and are prepared to pay for. Australian Governments have not yet responded to this advocacy - not even the 20-year-long Liberal Government that was supposed to be in the pocket of the private sector. Nor does it seem to be the case that the research conducted by government laboratories was directed to the satisfaction of the private sector's needs. The vociferous complaints of the secondary industry sector, at any rate, were that neither of the big spenders of the Government's science dollar - CSIRO and DSTO - contributed much at all to industry.

The simple fact of the matter is those who participate in the policy processes, and society generally, have not seen Australian science as having a great instrumental role in tackling the range of national problems that, elsewhere, have provided the major justifications for investment in science and technology. Instead of turning to science and technology to relieve our national anxieties, it has been our habit to seek out economic, political and diplomatic bargains to gain access to the instrumental science and technology we have needed or to block threats from innovating foreign technology.

Except for defence science and technology (a good part of which, anyway, appears to constitute a sophisticated purchasing office), Governments have had no great interest in the scientific activities they have supported so abundantly. Except in the crises of war, few claims have been made on the Australian scientific establishment and appropriations have followed the incremental principle. Similarly, there have been few institutional connections between the non-defence science and technology establishment and those in government, or elsewhere, who have the custody of national goals or who pursue operational programs that might benefit from science and technology inputs.

In sum: there has been no great demand for the products that our science and technology establishment might produce. Without social demand, and competing social demands, allocation problems can hardly exist. Those with the responsibility for formulating and implementing national goals have been largely uninformed and unconcerned about the potential of science and technology for those goals. Whatever competition has taken place between social ends it has not been accompanied by considerations of competing uses for scientific resources. Such competition would be likely to yield criteria that would enable Governments to take allocation decisions as between fields of science, problem areas and so on. Science and technology have not entered the processes of policy competition at all. Nor, because of the same factor, was it necessary until recent years to review the institutional and performance patterns to ensure linkages between the producers and users of science and technology inputs relevant to the pursuit of social, economic, health, environmental, and industrial objectives. The politics of Australian science has not been about the allocation of resources.

There have, though, been political questions, for there are values in addition to monetary ones which scientists seek. As one would expect from the Australian habit of locating many of its political conflicts at the administrative level, and from the predominant position that government has as a performer of science, the place to look for the politics of Australian science is in the bureaucracy.

With a couple of major exceptions the controversies that have involved Australian science have been about organisational and administrative matters but they have rarely broken the political surface. The exceptions have been in periods of Labor rule. The first occasion was in the late 1940s, during but only partly a product of our own little McCarthy period, when the Chifley Government introduced major amendments to the Science and Industry Research Act. The second, more recent, occasion was the emergence of organisational schizophrenia when, for a short period, a couple of CSIRO Divisions were shuffled about the administrative deck. On both occasions the scientific community raged and had some success; the matters were noticed elsewhere in the political system, but only just.

In the main, controversies have been at the administration level, handled by relatively few people, and have caused scarcely a ripple on the political surface. They have related to the defence of the administrative components of autonomy by CSIRO (and one or two other science corporations) which the founding fathers of organised research in Australia were able to gain as early as 1916. Or they have been the efforts to secure similar degrees of autonomy by significant groupings of scientists elsewhere in government service, so far unsuccessful.

Although I must confess that I have not done the research to support my memory, I cannot think of an occasion prior to the early 1970s when there was controversy about a 'policy' matter concerning the programs or the uses of Australian science and technology. This applies both within the bureaucracy and the conventional political system. There have been no issues which sparked a wider public interest, let alone criticism.

Our science politics have been either very gross or very fine - gross, with respect to broad allocations as between performance sectors; fine, as to the administrative detail of research organisation and management. Gross or fine, there has been no close or continuing relationship between science and the political system and no great social demand for science outputs. Concurrently, a reasonable quantity of resources flowed from governments to their own science organisations and to the universities, but the minimal pressure from industry for government funding of industry research met no response.

2. CHANGING POLITICS

Of course, over this period a number of people and organisations believed that things ought to be different, and urged the adoption of science policies and science policy machinery. What the policies were designed to achieve, and what the machinery was supposed to do, however, varied with the advocate. There are now a number of reviews of our faltering steps towards the adoption of a 'science policy', the most recent of which have been referred to above. Very few, however, have gone so far as to advocate the involvement of science and politics. Indeed the creation of science policy machinery can often be seen as a desire to protect science from politics.

The years immediately after 1972 seemed to promise a closer relationship between science and politics. There was much talk of 'people-oriented' science and of 'science for the people'. What the phrases and their use actually mean and meant are by no means clear. In an unfavourable interpretation, Shils[5] has suggested that the phrases are the slogans of an anti-science movement, nurtured, if not impelled, by the strident science policy analytical profession. Their use is dangerous, Shils argues, because it carries an animosity towards the modes of leadership of the scientific community and towards the prevailing ethos of the scientific community. The use of the slogan in Australia may have been simply a way for ambitious or revengeful politicians who had a temporary custody of science affairs to pursue their ambitions or their revenge. A much more generous interpretation has been offered by Rubenstein.[2] He sees the phrase and its use as expressions of a concern that science and technology be used most effectively as a means in the pursuit of non-scientific objectives. No matter the intention, scientists were often discomfited and puzzled by government actions between 1972 and 1975. This was especially so when towards the end of Labor's rule 'effective cutbacks in medical and university research in the August 1975 Budget compounded these problems and reflected the low concern and even confusion about science, indicating the chasm between promise and performance.' The traditional disinterest of Australian governments in science affairs prevailed over the rhetoric, the planks of Labor's Science Policy platform and the noble statements and proposals about government science made by the Labor Party Leader in 1970.[6]

The movement toward the political threshhold may be accelerating, and we may soon cross it. There are a number of background factors. Although the most significant formulations and exchanges of views are, in the Australian tradition, still below the political surface, they are increasing in number. Encouragement comes from the multiplicity of Inquiries which, beginning in Labor's period, continue at much the same pace. These include, the IAC Inquiry into Rural Research; aspects of the Jackson Committee Inquiry into Manufacturing Industry; the RCAGA and especially its Science Task Force; ASTEC's Inquiry into itself and its continuing inquiries in the discharge of its redefined and governmentally approved role; the Birch Inquiry into CSIRO; the Howson Inquiry into the Bureau of Meteorology; the Townshend Inquiry into the BMR; and the projected NERDDEC Inquiry into the AEC. There may be no end to this because of the built-in exponential - inquiry reports contain recommendations for further inquiries. The buck, however, might stop with ASTEC, as ASTEC's second order inquiries into the results of other inquiries have commenced.

Whatever the fate of the recommendations that come from these various inquiries, their most significant consequence is that they have forced a number of government departments and agencies, and perhaps some industry bodies, to think about the relevance of science and technology to their policy objectives or programs. An increasingly larger number of departments now need to take a 'position' in relation to these inquiries and their recommendations. The discussion of 'science as a means' in departments and agencies is now much wider than it was five years ago. Though many questions remain controversial, and to be resolved, the change is a major one for it suggests that the nucleation of demand, for science and technology, in the mission agencies of government may be beginning.

A second factor is that science and technology are being dragged into politics as the objectives which they do, or ought to, serve become increasingly controversial and thus of greater interest to governments. Many of our major technological efforts have been long blessed with the peace of corporate autonomy - energy supply authorities, water supply agencies, specific resource conservation bodies are examples. The status of the corporation originally was a way of isolating these activities from the world of politics. That is no longer possible and such bodies themselves are seeking the protection of the political system as their objectives and programs are being subjected to scrutiny, criticism and protest by a range of community groups whose interests diverge considerably.

Energy is a particular case. The push towards politics comes not only from protest groups and critics who may be concerned either with greater efficiency or different lifestyles, but also from governments concerned about future scarcities and costs. The political system is readjusting itself to cope with energy issues. Changes are being made in the institutions that serve energy policy, including the research and development component, to bring energy R&D closer to the points of policy formulation and implementation. It is certain that the energy part of the science and technology establishment will be much more intimately involved with politics. It will face closer scrutiny, and the harder choices will be based on more coherently defined criteria drawn from the political and administrative systems, now much more interested in science and technology.

Third, is the pattern of restraint in government expenditure which extends across the board. However, it is not all slow down. Energy research funds have increased and more is to come. There is the beginning of an increase in funds for research in industry and the adoption of more effective means to increase industrial awareness of the benefits of science and technology to production. As well, the government has adopted mechanisms for encouraging research in the marine sciences and technologies. The general restraint, however, does pose painful choices across the broad spectrum of science and technology, although it has not led to the soul-searching evident in the USA in the early 1970s.[7] The reason is, I think, that so far the government has been sensible enough to allow the still largely autonomous science organisations to set their own priorities in accomplishing the cut-backs in their appropriations. They are, however, exhorted to take cognisance of national goals. For example, in his recent address to the Academy of Technological Sciences, the Prime Minister said: 'We look forward to CSIRO using its extensive research resources to provide greater support to the development of improved technology for primary, secondary and tertiary industry.'[8] Moreover, in the recent amendments to the Science and Industry Research Act, which were a response to the Birch Inquiry Report, the government has provided for modified organisational structures whose aims are to facilitate relationships between CSIRO research and the operational agencies or production units. It is still too early to judge whether the exhortations and the organisational innovations will result in the reallocation of resources required, if the twin objectives of restraint and change in research programs are to be satisfied.

The permanent creation of ASTEC and its attachment to the Prime Minister is a fourth factor. Pehaps more important, the attachment is to a current Prime Minister obviously interested in science affairs. Whatever views one might have about the virtues of the various ASTECs, their constitutions, roles and compositions, the most significant fact about the permanent ASTEC is this particular attachment. Professor Badger discusses policy machinery, so I do not want to explore ASTEC's role and functions. I do, though, want to draw a couple of lessons about the relations between science and politics from that most significant fact. The political responses to the creation of ASTEC have been at two levels - at the political level proper, and within the administrative system. At the administrative level, the common fate of a newly introduced advisory body is to be suppressed or rejected as the immunological system starts to work.[9] ASTEC, however - as it seems from my rather interested position - has, in fact, caused changes in the administrative system itself. The various departments and agencies have become more conscious of the likelihood that competing views about the science and technology components of departmental proposals might find their way to the Cabinet through the Prime Minister. Just as important are the responses at the political level. These are of two kinds. As a consequence of the departmental responses, Ministers will themselves be more knowledgeable and better informed as they carry the proposal to Cabinet. Moreover, Ministers are now in the position to seek the advice of ASTEC, through the Prime Minister, in their own consideration of the programs they wish to see pursued in their departments. The existence of ASTEC, and its attachment to the Prime Minister, thus can enhance the positive exercise of Ministerial responsibility. I would guess that - at the very least coincident with ASTEC - the Cabinet is now devoting much more time to the consideration of science and technology issues. There can be no doubt that the quality of political debate on such issues in the Parliament has increased enormously since ASTEC came into existence and great reliance has been placed on ASTEC reports in those debates. The Parliamentary debates on the Bills to establish ASTEC and to amend the Science and Industry Research Act last year are probably the best informed debates on science and technology in the history of the Federation - inside or outside the Parliament.

Science is not quite in politics yet, but it is moving there fast.

3. LIKELY DEVELOPMENTS

What is likely to happen when science and politics become more intimately associated? When social demands are made on science through the political system rather than the situation that has prevailed until now; a situation in which the social use of research results has depended on a limited number of scientists taking their results to potential users and having a very hard job trying to persuade those users to innovate. There is very little dissent from the general view that science should be brought to bear on national goals but there are two competing views about what should be done to connect science with social purposes. These views are usefully summarised in the papers by Ronayne and Rubenstein mentioned earlier, though versions of them appear in many places, including some of the reports from the Inquiries referred to above.

One view sees the need to bend science organisations and scientists towards national objectives clarified and defined so as to provide criteria for choice in the allocation of science and technology resources. This view implies, immediately, some central policy apparatus; some form of science budget; the possibility that national goals can be specified in operational terms that have meaning to science agencies and which can be passed on through the central policy apparatus; and that scientific research be directed. Frequently, too, the view stresses the need for the stimulation of science policy studies to provide inputs for the decision processes and for which a central policy apparatus would be both major benefactor and major customer.[10] The concentration is on the science and technology establishment and its programs.

The alternative view sees the formulation of choices about operational programs designed to serve national goals (and science and technology are simply one aspect of such operational choices) as essentially political in character. The choices are determined through a complex political process where, at a multiplicity of decison points, national goals change in emphasis and direction over time and 'there is no unchanging, monolithic, set of political priorities and objectives'[2] that can provide long-run criteria for a central science policy body to pass on to research agencies. Thus, this view emphasises the need to establish effective communications networks between the producers and users of science and technology inputs to stimulate interaction between them. It is a much more difficult solution than central direction seems to be to the problem of connecting science with national goals.

The Science Task Force of the Royal Commission on Australian Government Administration recognised this complexity. Its 1975 recommendations urged the need for the multiplicity of decision points in the government sector, and in a good part of industry, to have science capacities that would enable science and technology factors to influence the definition of operational goals at these decision points but which, at the same time, could link back to a diverse scientific community transmitting social demands in ways comprehensible to the scientific establishment.[11] The discussion which followed the release of the Task Force Report was very largely a rush to defend professional or organisational interests which the Task Force had questioned. The antagonists ignored, or as Rubinstein has noted, misunderstood this major focus of the Task Force Report.

The two views most certainly rest on differing political philosophies. I doubt the possibility of reconciling them. This paper is written with a bias in favour of 'diversity and adaptability', and in the belief that a central policy apparatus endeavouring to bend science is much more likely to break it, but that, anyway, central direction through a central policy apparatus will be ineffective in linking science to social purposes. In complex political systems central coordination and direction can only be at the cost of program achievement.

The emerging pattern of interaction between science and politics in Australia is, I believe, in general conformity with the second view outlined. Although I don't want to claim that the Science Task Force Report was directly influential in shaping this pattern, I would go a little further than its principal author is prepared to do.[12] The Report has stimulated discussion. It identified a major deficiency in the capacities of government agencies to inform themselves of the relevance of science and technology to their missions. Its arguments were heard in many agencies which recognised the need for a response. The responses have not always been in accordance with the recommendations - we were not universally and eternally wise. But the need to establish communications and linkages between mission body and research agency has been recognised, and is now an accepted premise in most governmental discussions about science and technology. The Prime Minister, for example, has said this:

> 'Technology and science interact, and the more we can understand and manage this interaction, the more practical benefits the community will derive from Australian scientific and technological expertise. It is essential that our organisational arrangements reflect this basic need and the closest links and cooperation be forged between government departments, government research institutions, industry and the academic world.'[8]

There is still a need to improve the 'science capacities' of many mission departments, and, of course, of the great bulk of firms in the industrial sectors. At the risk again of intruding on Professor Badger, it seems to me that ASTEC is playing a useful role here. Though it has certainly not come down on one side or the other in the competition between the views I mention - nor indeed considered the matter directly - many of its recommendations have been directed to improving the 'science policy capacities' of various policy areas. It has proposed means for the effective interaction and communication of scientists and technologists with those taking operational and program decisions in those policy areas. With respect to industry, the Department of Productivity is similarly looking for means whereby the manufacturing sector, particularly, can be served by effective information and liaison services linking firms to relevant research groups to their mutual understanding. As these capacities improve, the interaction between science and politics will become more sophisticated and, I believe, more profitable to both.

4. AUSTRALIAN LESSONS FOR DEVELOPING COUNTRIES

Australian science has grown without pressing social demands being placed upon it. Because there have been no premature social demands, the Australian scientific establishment has reached a position of considerable sophistication. It draws strength from a long period of development and maturation. It has remarkable accomplishments. It has accumulated considerable experience in the leadership and management of scientific and technological activities. Perhaps most significant of all, the leaders of the Australian scientific community now emerge from the community itself. Australian science and technology are now capable of responding to social demands as and when those demands are articulated through the political system.

The political and administrative systems need to develop more sophisticated capacities to handle science and technology affairs and to clarify social demands in terms meaningful to the scientific community. The process is beginning.

It is necessary, then, for both science and politics to develop optimal degrees of sophistication before each can interact with the other to the national benefit. In Australia both development processes have been slow, but we were able to buy the time through economic and political pacts and bargains that diverted social demands.

In other countries the urgent category of time, and the lack of resources with which to bargain, might lead to premature demands being placed on embryonic scientific communities. Few Third World countries have a scientific tradition. In most, the science and technology professions have emerged only in the last generation. Most scientists and technologists are young, as are the leaders of the scientific communities. Very few of their national science and technology organisations have developed the organisational experience, skills, memory and strengths to enable them to interact effectively with a political system. Very few of their political systems have developed the sophisticated coordinating capacities essential in connecting science and technology with developmental objectives. There is a great danger that premature and immature demands will be placed on science.

The Australian lesson is that time must elapse before both science and politics are mature enough to interact. Perhaps Australia allowed too much time, but that should not obscure the lesson.

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THE EFFECT OF INSTITUTIONAL EVOLUTION ON SCIENCE POLICY

BY

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INSTITUTIONAL ASPECTS OF CHANGE

George Basalla has developed a model of the diffusion of Western science to countries outside Europe and of the stages of development that science appears to take in a new environment. Basalla postulates three stages of development: the period of immediate scientific transmission, when a newly opened territory provides a fresh source of data for European science; the period of 'colonial', Western scientific endeavour, when indigenous scientists enlarge the spectrum of their interests and accept fuller responsibility for the investigation and interpretation of the scientific world; and the final stage, when colonial scientists build self-supporting institutions, receive scientific training in their own country, develop independent societies, and formulate indigenous scientific attitudes and goals. Additionally, Basalla states that real scientific independence and self-reliance begins with the production of scientific instruments and with the technological creativity that provides an independent stronghold in modern science.[1]

Historians and sociologists of science have questioned the accuracy and universality of Basalla's model and whether the experiences of different countries conform to or diverge from his broad categorisation of 'stage'. However, it is clear that each country will reach a comparative level of scientific development, institutional growth, and technological capability at different times, and that a nation's particular history and environment will impart decisive characteristics to its scientific and technological mould.

The model is useful for the United Nations Conference on Science and Technology for Development. It, however, needs one extension. Basalla was writing in 1967. Since then, many countries have experienced a further stage of 'scientific growth'. They have begun to assess their indigenous scientific goals and evaluate organisational and financial arrangements for the 'best' deployment of their national science. In an extension of stages Basalla did not foresee, nations have come to ask critical economic, social, and political questions about the purpose, impact and directions of science and technology.

Where does Australia stand within these models of growth? Clearly she had reached the third stage of scientific progress by the third decade of the twentieth century. Australia would appear to support a science commitment that is relatively high, ranking ninth both in the proportion of scientific papers published and in the proportion of Gross National Product (GNP) spent on R&D when compared with other countries.[2][3] On a per capita basis Australia's expenditure is in the same league as Japan, Canada and the UK.[4] As de Solla Price has suggested, Australia, in respect of expenditure on science, spends 'somewhere between exactly the amount it should have and 20% more than that amount'.[5]

While international comparisons of R&D are instructive there are some fundamental features which have distinctively shaped Australia's scientific development in the past 60 years. Australia is noticeable in world science in financing a major proportion of her R&D from government funds and performing a significant section of her research and development in government laboratories. Governments financed 70% of R&D in 1969 and 62% in 1973-74. In 1973-74, 42% of her R&D was carried out by Governments, 35% by business enterprise, and 21% by the higher education sector.[4][6][7] This pattern of R&D expenditure in Australia has some common features with less developed countries.

It is thus clear that Australia's policy for scientific R&D is closely linked with her government institutional growth. It is also linked with the historical recognition that, in a country where research and development flowed primarily from government support, Australian industry was not likely to undertake a significant amount of scientific research.[8]

This paper concentrates on institutional aspects of Australia's resource allocation in science. Australia has now entered the period of critical appraisal of her scientific estate and is engaged on the examination and formulation of the next phase of her scientific development. An overview of our historical institutional experience may therefore usefully illuminate our contemporary concerns and offer pointers and comparisons to other countries.

THE INSTITUTIONAL PATTERN

Alvin Weinberg, in an analysis of 'Institutions and Strategies in the Planning of Research', has contended that two major routes lie open to both countries and individual organisations in the way they organise their research activities. 'Given a large governmentally set scientific objective and given resources to achieve that objective', he writes, 'should a plan be made to focus primarily on the specific scientific-technical directions to be pursued, or should the policy aim at developing the appropriate means - scientists, laboratories, research and development contracting organisations - for accomplishing the objective?'[9] The first choice represents the 'strategic', the second, the 'institutional', approach to science policy.

In setting up its first major national research organisation, the CSIR, in 1926, the Australian Government set its course directly along the institutional route. The Council for Scientific and Industrial Research (CSIR) was conceived by a Government who sought a central scientific research institute geared to Australia's pressing agricultural and pastoral problems and committed to providing a reservoir of fundamental and appropriately applied research. In 1937, CSIR added secondary industry to its research concerns and set up the National Standards Laboratory. As war approached, it turned to a range of industrial and defence research activities and gained a world lead in the development of radar and radio astronomy.

CSIR's involvement in wartime research was to lead to its first reconstitition by Act of Parliament as the Commonwealth Scientific and Industrial Research Organization (CSIRO) in 1949, when areas of secret defence science were transferred to the Ministry of Supply.[10] The transfer emphasised one essential part of the Organization's goal; that of open, high-quality research published in the scientific literature and available to peer review. The second part was the investigation of important national scientific problems and the provision of the 'best man' to solve the task. Characteristically, the first definition of the Executive's function within CSIR was spelled out as (i) not to act as scientific directors or judges of results; (ii) to determine, on the best available advice, what problems should be attacked; (iii) to find the best man to put in charge of the investigation of such problems; and (iv) to provide full opportunities for such men to solve these problems.[11]

These broad aims have stamped the character of the Organization over 50 years and match Weinberg's definition of the institutionalist approach. Institutionalists, he confirms 'view their primary function as the establishment and nuturing of their institute: ... they focus first of all on recruiting good scientists and providing them with support.'[9]

Accordingly the cultivation of autonomy within the research system has become the hallmark of CSIR(O). Divisions have multiplied from the original 4 to 37 in 1978 and research now spans vastly diverse areas. The CSIRO 'culture' has grown on the principle of fitting organisational arrangements to individuals' research and of encouraging creativity and diversity. The consequence, it is argued, is that research ideas and initiative have flowed upward from the researcher and that institutional policies have been generated and shaped at the frontier points of research and rather than at the heirarcical level of the Executive [11][12][13][14] The Executive, however, has played a prominent part in the framing of overall institutional policy, and, at the national level, as an influential advisory group in the shaping of science policy. CSIRO's budget has risen exponentially from an initial budget of A45,000 pounds in 1926 to $135.4 million in 1977-78. The Organization now employs some 7000 people, of whom 2000 are professional scientists and experimental officers. CSIRO employs approximately one third of Australia's trained scientists and consumes over 21% of the national GERD.

CSIRO has been widely recognised as an organisation of high scientific quality with broadly defined scientific goals and has served as a model for several countries overseas. But within its half century's evolution, several discernible problems have emerged from its history. Queries have been raised as to its proper reflection, in changing national and scientific circumstances, of the country's scientific and technological goals. Is it sufficient to get the best man for the job and channel resources to him? Should there not be greater emphasis on missions and needs? The OECD Examiners, reflecting local criticisms, concluded that the Organization's use of resources was not 'as effective as it ought to be in the overall national interest' and posed certain questions. 'Is CSIRO too big to be effectively managed? Is its activity too dispersed and lacking coherent policy? Are its methods, excellent in the past, still appropriate to the conditions of today? Are its programs devised with sufficient appreciation of the needs of the users of its results. Does it carry out sufficient work for manufacturing industry compared with the rural sector? Are its relations with the universities sufficiently close?'

These questions were addressed by the Independent Inquiry into CSIRO commissioned by the Federal Government in 1976. The Birch Report, presented to the Government in August 1977, marks a major step in Australia's science policy developments. It may be debated that, as one MP put it, 'Australia has achieved perhaps the most intense investigation into a science and research organisation that has ever occurred in any country.'[15] However, the Inquiry, set against a broad overview of government science in the UK, France, Canada, Norway, West Germany, the USA, USSR, Japan and New Zealand, carried out a detailed evaluation of the function and operation of CSIRO and made 122 recommendations to Government.[16]

Fundamentally, the recommendations aimed at providing CSIRO with more responsibility and flexibility and at bringing the Organization into closer and more active relationship with the scientific, industrial and user community. While the autonomy of science and the right of scientists to take responsibility for scientific decisions are carefully preserved, the Report sees CSIRO's principal role as filling a gap in national research with 'strategic mission-oriented work which would otherwise remain unfulfilled'. CSIRO will continue to carry out fundamental research in areas of national and international interest, and to develop tactical problem-solving research for short-term needs. Research will concentrate on the physical and biological sciences, with special emphasis on Australia's national capacities and priorities, which will include work for primary, secondary and tertiary industry. Research, it is underlined, should take account of Australia's international obligations and give particular attention to the provision of scientific research and training activities in developing countries.

These recommendations offer both some reaffirmation and some specific redefinition of CSIRO's role. Importantly the Report provided for changes in the structure of CSIRO, notably in the grouping of the Divisions into Research Institutes to concentrate and cross-fertilise research activities and to provide for more coherent relationships between Divisions and national sectors. The Executive will remain responsible for broad overall policy and strategic planning, the allocation of resources among Institutes and the coordination of Institute programs. However, it will no longer perform its historically accepted function of providing advice to Government on broad scientific and technological policy - a role now seen as devolving on the broad national shoulders of the Australian Science and Technology Council (ASTEC).

Intrinsically, the Birch Report sought some softening of CSIRO's traditionally independent and 'monolithic' role. It advised that CSIRO should accept greater accountability in defining and presenting at appropriate intervals 'the main thrusts of its broad policies and more detailed objectives for government, parliamentary and community scrutiny'. It also recommended that the Organization should seek to disseminate information from international science and technological innovation to benefit Australian technological innovation and for increased use by national industry. Central also to its recommendations is a concern to revitalise and strengthen CSIRO's consultative and advisory machinery. At the same time, the Report advised that CSIRO should contribute to developing the role of Research Associations and seek routes for the larger contracting out to, and collaboration with, Australian industry.

In sum, the Birch Report highlighted the necessity for institutional adaptation in a period particularly susceptible to manufacturing needs. It exposed an acknowledged dysfunction, perhaps the 'compass error', in CSIRO's historical performance in its overall failure to provide adequate support and stimulus to Australia's weak manufacturing industry, despite its patents policy and development project work.

Two important, but not unconnected, recommendations of the Report highlight CSIRO's relations with tertiary institutions, and the age profile of the Organization's research staff. From its inception, CSIR's founders, and notably Sir David Rivett, conceived of the new body as 'the ultimate university' in Australia. With substantially greater research facilities and research funding than universities (at least until the creation of the Australian National University in 1946), CSIRO has developed what the Birch Report describes as 'quite close but uneasy' relations with the universities and colleges of advanced education (CAE). The Report accordingly recommended 'the forging of closer links' between CSIRO and tertiary institutions through setting up joint 'centres of excellence', siting new CSIRO laboratories near tertiary institutions, sharing equipment and facilities, increased methods of interpenetration through staff exchange, and possible contracting out to universities and CAEs work related to CSIRO research programs.

In respect of CSIRO's staff profiles, the Report noted the persistent upward shift in the proportion of senior research to its total research staff in the past decade. It recommended that the proportion of fixed term to indefinite appointments be raised and a voluntary retiring age for 'low efficiency' scientists be introduced. The prospect of management-initiated retirement, with satisfactory agreements, has also been intimated for assisting manpower management.

The Birch Report, in its careful explication and recommendations, cut a significant swathe of potential reform through Australia's premier scientific institution. As its recommedations advised that the thrust of the reforms be embodied in legislation, the Science and Industry

Research Amendment Bill - the first legislation to affect the Organization since its reconstruction in 1949 - was before both Houses of Parliament in October-November 1978.

Much will depend on the serious implementation of the Act. Political responses have shown large consensus. Government and Opposition have praised the scientific quality and achievement of CSIRO, but both allow that there is evidence of a substantial gap between the Organization and manufacturing industry.[17] The Government has agreed that the scientific autonomy of CSIRO should remain intact; that the dissemination of research results should continue to be a function of CSIRO subject only to a general power of the Minister for Science to provide guidelines to the Executive;[18] and that a revised and strengthened advisory and consultative machinery drawing on users of research be set up to assist in the determination of strategy and program priorities. Opposition spokesmen on science have particularly stressed the need for greater relevance and accountability in research and its flow-through to developmental projects, and have placed additional emphasis on the social and environmental aspects of CSIRO's work.

The ultimate outcome of the Birch Report and its reforms must inevitably reside in the measure of accountability demonstrated by the 'reconditioned' institution and in the parliamentary interest and scrutiny this invites. The high level of interest, information and awareness demonstrated by speakers from both sides of both Houses of Parliament on the Ministerial Statements and the Science and Industry Research Amendment Bill is a promising pointer to active parliamentary review. CSIRO Annual Reports will also need to provide more detailed and cogent statements of the thrusts and results of changed, terminated or newly intiated undertakings. There could be less gloss and some indication of errors and disppointments as well as of missions accomplished.

Finally, is the Birch Report, as one politician has questioned, really a 'radical critique' of the Organization? The point raises larger questions. In all organisational change the conservatism of the institution plays a recognised part. An innate resistance to external decision-making remains central to institutional response.[19] Will the bureaucracy, then, both in Government, CSIRO and universities - as has been suggested[20] - 'absorb the changes', and thus dilute the real potential of a major experiment in institutional science policy making?

STRATEGIC POLICY MAKING

The development of Australia's second civilian scientific instititution differed distinctively from that of CSIRO and has been skewed from the outset to 'strategic' goals. The Australian Atomic Energy Commission (AAEC) was set up in 1953 in the Cold War period, when major industrial nations were developing nuclear technology and when Australia was experiencing a post-war sense of 'technological nakedness'. It marked the establishment of an organisation with precise objectives, and a strategically orientated master plan around which the planners could build their scientific and logistic support.[9]

The AAEC was constituted by Act of Parliament (the Atomic Energy Act of 1953) as a statutory body responsible to the Minister (who was not specified). It was charged with promoting the discovery, mining, treatment and processing of uranium ore, the operation and construction of plant for the liberation and conversion of atomic energy; and the training of nuclear researchers. The purposes embodied in the legislation were to make use of Australia's important, but then scarce, uranium reserves, to gain access to the emerging body of nuclear knowledge abroad, to launch Australia as an independent and creative participant in research in the nuclear discipline, and to involve Australian industry in the Commission's active role in nuclear work.

The dominant strategy of this institution expressed by at least three Liberal Prime Ministers was 'to bring Australia into the nuclear age'. As Sir Philip Baxter, Chairman of the AAEC for 16 years, later summed up: 'The Government decided that the Commission was to create in Australia a team of experts and a pool of knowledge covering all important phases of the prosecution of nuclear power for industrial purposes.'[21] In practice, this meant the creation of the Research Establishment of Lucas Heights in 1955, a staff ceiling of 1000, and the entry of Commission teams into the investigation of a difficult and challenging technology - the development of a high-temperature gas-cooled power reactor concept using beryllium oxide as a moderator - which, it was judged, would gain Australia's access to broader nuclear expertise abroad. This mission proved abortive, though good work was done. Critics considered that the commitment itself and the protracted nature of the research from 1955-64 was not justified by the failures already experienced in beryllia technology by major nuclear nations overseas. But the venture was seen by AAEC teams and management as creating useful research, and as 'getting their feet wet' in nuclear investigations.[22] In the mid sixties, AAEC sought a second mission: the construction of a nuclear generating power reactor at Jervis Bay based on imported technology but involving considerable highly skilled scientific and technical work in connection with tendering, building, safety testing, and related research in nuclear science and engineering. The evaluation of tenders from overseas companies and the preparation and scientific testing of the selected site were abruptly terminated in 1972 when Prime Minister McMahon decided that the operation of a nuclear power plant in Australia must be based on costs comparable with conventional power, not on government subsidy.

The Government's decision to rescind the earlier policy to introduce civilian nuclear power stations in Australia had a paralysing impact on the AAEC. The institution lost its mission and there was neither Ministerial directive nor clear perception of its future role. In a period of hiatus and uncertainty, and under new leadership, the AAEC adopted a policy of 'wait and see'. The strategic master plan had been abandoned. 'Institutional' goals now crystallised: purposes became generalised; internal re-organisation occurred; the production of radioisotopes became pre-eminent; collaborative arrangements with universities were strengthened; and in-house research proceeded with growing concentration on uranium enrichment techniques. Yet, despite its lack of strategic mission, the AAEC continued to grow. In a period of significant budget checks, the AAEC annual allocation rose from $16 million in 1974-75 to $26 million in 1978-79. Contrastingly, the Australian Research Grants Committee (ARGC) funds declined from $22 million for the triennium in 1973-75 to $20 million for 1976-78 and the Bureau of Mineral Resources allocation fell from $16 million in 1972-73 to $13 million in 1977-78.

These contrasts in funding stirred criticism in scientific circles. The difficulty in assessing the perceived role and research undertakings of the AAEC was complicated by the extreme secrecy provisions of the original Atomic Energy Act and by the fact that, for the most part, AAEC publications were published internally without the operation of peer review. AAEC Annual Reports also shed only superficial light on the range and progress of central research tasks,[23] and have indeed, tended to mask work initiated outside the definitions of the original Act, notably in solar energy and nuclear fusion fields.[24]

What then was this altered institution for? The AAEC had moved markedly away from its original blueprint; there had been an exodus of good scientific staff; the senior research staff was ageing;[3] and considerable institutional demoralisation surrounded the loss of missions. At a time when overseas atomic laboratories were diversifying and contracting out their work to industry, the AAEC saw itself as 'keeping a watching brief' on nuclear technology and maintaining expertise on nuclear developments abroad. In-house research on centrifuge- and laser-enrichment technology was being pursued, but its merit and level of development could not be openly assessed.

Several central questions thus arise about the resource allocation and institutional future of the AAEC. Could the role of the Commission in keeping up to date on relevant nuclear know-how be more cheaply accomplished by the secondment of staff (as other countries have done) to nuclear bodies and regulatory bureaux abroad? Should the important Isotope Division be constituted as a separate statutory corporation? Could AAEC retrieve part of its original plan to relate to industry?[6] Could problems of staff seniority and some inflexibility in facing new directions be accommodated by evolving government approaches in the energy field?

The announcement by the Minister for National Development of a review of the research and development activities of the AAEC for completion in mid 1979 indicates that the institution's long period of scientific isolation and inaccountability is over.[25] The review will be undertaken by a committee under the aegis of the new National Energy Research, Development and Demonstrative Council (NERDDC) and will pay special attention to the needs and reasons for AAEC's present R&D in various fields and the degree to which each program is strategic, tactical or fundamental. The committee will also address itself to questions of overlaps with other government-sponsored R&D problems and with international undertakings. Importantly, the committee will consider the 'capacity of the Research Establishment to re-orientate its R&D role and to deploy both new and existing policies and broader energy R&D objectives'.

The committee's appointment represents a further, though some suggest long-overdue, attempt at the rationalisation of science and technology resources in Australia. While the AAEC clearly offers an important resource of national scientific facilities, equipment and men, the review committee must confront a task that may lead to the splintering of a major organisation. Staff may need to be re-deployed into new areas of activity and substantial change and re-interpretation of the Commission's role may be necessary. The possibility of regional relationships between a national laboratory and universities, a key feature in the US system, may prove appropriate.[26]

DEFENCE SCIENCE

There is no field of government scientific administration and resource commitment that attracts more critical and unanswered questions in Australia than defence science. What, in a traditional environment of national security, can be learnt about it? How efficient is it in terms of building up Australia's independent technology? How does it serve the broader interests of civilian science? Can defence science and technology, which constitutes the second largest concentration of Australia's R&D, be brought realistically within the discussion of changing resource commitments for science and technology?

Defence science research grew up in Australia in the wartime Department of Development and Supply and evolved through a concentration of four major laboratories: the Weapons Research Establishment, the Defence Standards Laboratories, the Aeronautical Research Laboratories, and the Central Studies Establishment. In 1973-74, defence science accounted for 13% of GERD,[4] holding second place after CSIRO. Reforms within the Defence Department in 1975 brought structural changes[27] and the Defence Science and Technology Organisation (DSTO) was established with eight Divisions. The four research-based Divisions are:

- the Aeronautical Research Laboratories;
- the Materials Research Laboratories;
- the Defence Research Centre, Salisbury; and
- the Service Laboratories and Trials Division.

The remaining Divisions are Military Studies and Operational Analysis, Policy and Project Planning, Science Administration Development, and the Australian Ordinance Council.

Total expenditure on defence research was $57 million in 1968-69, of which $54 million was spent intramurally and $3 million extramurally, all on the natural sciences. The intramural research program was in the hands of some 6000 personnel, some 20% of whom were professionally qualified scientists. In 1973-74, Project Score reported that 5093 personnel, 22% professionally qualified, were employed and $56 487 was spent on Defence R&D.[4] This figure, however, has been challenged as covering only the allocation to the R&D Division of the then Department of Supply. It excludes funds allocated to other activities, such as Production, Development and Navy, Army and Air Laboratories and Establishments, which remain hidden in the relevant departmental totals. These extra allocations increase the total figure to $76 million. Defence science hence makes up a more substantial percentage of our total R&D than published records suggest.[28]

Within these allocations, however, the OECD Examiners on Science and Technology noted that 'a proportion of the research and development efforts in defence is highly innovative, requiring high levels of skills', but that a large portion of the defence technology was 'somewhat restricted in scope and interest, being essentially devoted to testing, maintenance, tropicalisation etc.' The Examiners also observed that 'relatively little' defence research was contracted out to industry and practically none to universities. As a result, an in-house approach had developed that 'tends to become introspective, traditional and finally obsolescent'. They recommended that 'deliberate efforts should be made to encourage the growth of contract research to the extent, if necessary, of creating and aiding the growth of firms capable of evolving the necessary skills and techniques'.

Since 1974, a number of criticisms and questions about defence R&D have been publicly articulated in Australia. In a submission to the Science Task Force of the Royal Commission on Australian Government Administration in 1975, the Superintendent Scientists and Engineers at the then Weapons Research Establishment determined that 'a major impediment to the efficient use of available resources for defence research and development activities within the Public Service lay in the degree of control on their deployment imposed by authorities who are not concerned with the prime objectives',[29] of research development itself. Other submissions testified to a deep sense of frustration among defence establishment scientists.

More widely, the failure of the DSTO to build up contractual arrangements with industry and the scientific research community has prompted increasing criticism from industry and academia. Opinions presented to the Inquiry on Industrial R&D by the Senate Standing Committee on Science and the Environment concur that, despite OECD recommendations, the defence R&D system remains persistently in-house; that defence laboratories could be used more extensively for industrial research in peacetime; and that mechanisms could be established to develop and encourage defence contracts to industrial R&D and simultaneously stimulate industrial proposals to the defence sector.

Testimony submitted by a number of major industrial bodies hammered the need for industrial spin-off from Australian defence research funding and contrasted Australia's adverse position with that of comparable countries overseas. Hawker de Havilland pointed to the restriction suffered in Australia by the fact that industry can only obtain contracts for defence R&D for projects which have no staff target and which are limited to local usage. This condition imposes severe checks on potential production and contrasts markedly with the situation, for example, of Sweden, France and Canada. Hawker de Havilland indicated some areas where industrial defence collaboration might be of special relevance for Australia's developing neighbours. These include the design and development of para-military equipment, for example, 'surveillance aircraft, target drones, surveillance drones and pods, patrol boats, sonobuoys and radars'. Such equipment, while not turning Australia into an 'arms dealer', could lead to important market development in the Pacific and South East Asia.

These suggestions invite examination. The defence sector has consistently tended to counter criticisms with negative complaisance. They see the role of the DSTO as maintaining a data base for Service use on 'the state of the art in defence science and technology'; in gaining access to overseas technology through cooperative programs and arrangements; in keeping abreast of laboratory techniques; and in undertaking studies of major equipment.[30] Despite one injunction of the Tange Report 'to review the possibility of removing certain research, development, trials and evaluation functions to civil laboratories', or alternatively funding the performance of civil work in defence laboratories, defence science leaders contend that experience has shown that in-house resources for research proves 'surprisingly more flexible'.[31] They also stress the difficulties, in the present industrial situation, of assembling research teams with a wide diversity of skills in a reasonable time. Defence research, it is argued, cannot be readily transferred to the civil field. There is some recognition that the extensive number of checks and balances imposed on staff should be reformed and that 'blimpish judgments' should not be allowed to hinder the creativity of innovative defence research. There is little indication, though, that the DSTO has constructively considered new approaches to collaborate undertakings with civilian resources. The question of sharing defence R&D facilities with university projects has yet to be widely ventilated. Farrands, Chief Defence Scientist, countered the suggestion in 1975. 'It is recognised that universities are generally not equipped administratively to handle large systems investigations'.

Defence research decisions and the criteria by which they are taken have, as Peres points out,[12] been subjected to less public discussion than that of other fields, but they remain central to our national innovative capability. ASTEC has left the area outside the ambit of its first Report (Volume 1A), but the prospective Report of the Senate Standing Committee on Science and the Environment on Industrial R&D must confront the implications of the wide and pertinent evidence given to it. Essentially, the DSTO would seem to combine both an institutional and strategic approach to its R&D undertaking: a combination which, it could be argued, draws the least effective from both worlds. The Science Task Force has drawn attention to the need that government spending on new science projects in defence (as in civilian science) should 'in part be through research contracts'.[29] It urged that greater flexibility be encouraged within the defence science sector to counter aspects of administrative rigidity. Problems of frustration and creativity clearly impinge on the comparatively youthful DSTO staff, 44% of whom are under 35. In contrast to CSIRO and AAEC, with their growing aggregations of senior staff, only 26% of DSTO staff were graded as Principal and Senior Principal Research Scientists in 1977 (cf. CSIRO 49% and AAEC 41%).[3] The difference arises because, although eligibility for promotion in DSTO depends on performance, actual promotion depends on the availability of a position in the organisational structure. There may hence be a hidden ageing tendency within the lower classifications of staff. There is, inevitably, loss of incentive and low morale which could have consequences for the introduction of different approaches and new ideas.

The recent appointment of Professor Fink, former Professor of Mechanical Engineering at the University of NSW, as Chief Defence Scientist, suggests an internal change in DSTO and a possible advancement towards a closer interface with industry. A Commission of Inquiry into the Organisation has been called for in the House of Representatives.[17] Defence science now appears to be the area most in need of 'research on research'.

OTHER INSTITUTIONS

Three other Commissions of Inquiry have been instituted in the past two years to inquire into three other long established institutions: the Bureau of Meteorology, founded 1908; the Astronomical Observatories, whose origins lie in the nineteenth century; and the Bureau of Mineral Resources, founded in 1946. The Bureau of Meteorology will continue within the Department of Science but served by a Meteorology Policy Committee commissioned to overview its activities and to advise the Minister of its functions.[32] The Astronomical Observatories will be adapted and developed, where appropriate, as national facilities to be overseen by an Astronomical Review Committee responsible to the Minister for Science and the Environment.[33] The Bureau of Mineral Resources, once the scientific arm of Government in the fields of geology and geophysics, has been downgraded. Critics suggest it faces the prospect of becoming a 'moribund institution', with consequent low morale.[34]

At the same time, other scientific enterprises have been upgraded. For example, the Australian Institute of Marine Science, established at James Cook University in 1970, has given increasing visability to marine science. A scientific enterprise which, along with oceanography, ASTEC sees as an important area for development in Australia[3] has been stimulated.

Trends of change have also affected the Australian Research Grants Committee (ARGC), established in 1965. Its annual grants of funds to projects and researchers (predominantly in universities) of demonstrated excellence has risen dramatically from an initial $4 million in 1965 to $12 million in 1978-79. Yet the system invites questions. The greater part of ARGC grants flows to the natural sciences - 74% in 1972 - with only 13% going to humanities and the social sciences, and 13% to engineering and applied science. There is a need for an analysis of the effects of this 14-year-old funding scheme. The ARGC has, as the OECD Examiners remarked, fulfilled one part of the task of a research council in supporting research activities, but it has not yet, in their view, pursued 'an effective research strategy' in concentrating finance and directing support to specifically defined scientific areas.[6] The question of augmenting ARGC's resources has been pressed by ASTEC.[3] The more difficult matter of using ARGC as a means of pinpointing and building up research areas for development (perhaps in particular universities) is an important one for debate in a more determinist environment of resource allocation.

Similar developmental trends have also marked the allocation of funds for the support of industrial innovation. The Industrial Research and Development Act and Board were established in 1965 and amended as the Industrial Research and Incentives Act of 1973. The budget allocation of $24 million for industrial innovation in 1978-79 was a significant extension. The Government's intervention in a difficult phase in our manufacturing history may, it is suggested, yet provide the springboard of creativity and technological self-reliance that Basalla judged as mandatory for scientific and technological maturity.

CONCLUSIONS

It is apparent that mammoth changes are taking place in the organisation of Australian science and technology. The impetus has come from the changed climate of public opinion, from political responses, and from the establishment of ASTEC. In the 1970s, the politics of science, as Peres has pointed out, has moved us from a period of fragmented, laissez-faire, ad hoc arrangements of our scientific estate to a more cogent analysis of our overall resources. ASTEC's establishment as a statutory body responsible to the Prime Minister has already fostered a more centralised view - a view that the Commissions of Inquiry are endorsing. Despite the Interim ASTEC's disclaimer that there is 'as yet no developed science policy framework to provide a background against which ... priority judgments can be made',[35] the need to measure one set of claims against another has already been accepted. Attempts have been made to locate and express new balances within the budget for scientific R&D. Large questions of concentration, overlap, balance, and flexibility remain and cannot all be resolved by ASTEC. A mechanism advanced by the Coombs Report on Government Administration was a 'Council of Government Science Establishments' broadly representative of the scientific management of the scientific institutions, 'but with membership overlapping with ASTEC'. Such a Council could advise Government on organisational and other problems, check overlap, look to the question of staff mobility, and provide an important channel of communication for those responsible for the management of science-based work other than through departments and agencies.[29] The Council was further pressed in Parliament by Dr Klugman as providing a means of transferring and terminating programs with minimum damage to staff involved.[17]

Finally, one further mechanism has been canvassed in Australia which grows directly from our introspective concerns, that of technology assessment. The Technology Assessment Workshop sponsored by the Department of Science in 1978 noted the importance of anticipative action in planning technology and emphasised the need to develop a mechanism appropriate for Australia. The mechanism, seen by the Minister of Science and the Environment as a 'component of an early warning system designed to mitigate or prevent negative consequences and to identify positive opportunities of technical development',[36] has yet to be formulated.

Institutional change lies at the core of Australia's diversifying policy for science and technology. A satisfactory analysis and evaluation of the issues raised by this paper would require another essay.

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ADMINISTRATIVE ASPECTS OF SCIENCE POLICY IN AUSTRALIA

BY

G.M. BADGER

Professor G.M. Badger gained his MSc from the University of Melbourne in 1938, his PhD from London University in 1941 and his DSc from Glasgow University in 1949. He returned to Australia in 1949 as a Senior Lecturer at the University of Adelaide, and became Professor of Organic Chemistry in 1955. He held that position until 1964 when he joined the Executive of CSIRO. In 1966, he became Deputy Vice-Chancellor of the University of Adelaide and from 1967-77 he was Vice-Chancellor.

Professor Badger has made a number of important contributions to organic chemistry and his work has been recognised by the award of a number of named lectureships, medals and other honours.

Professor Badger has been very active in the work of professional societies. He is a Fellow of the Royal Australian Chemical Institute and the Royal Institute of Chemistry and a Fellow of the Australian Academy of Science. He was President of the Academy 1974-78, President of the Royal Australian Chemical Institute in 1964-65 and President of the Chemistry Section of ANZAAS in 1972.

Professor Badger has been an adviser to Government for some 15 years and was an original member of the Australian Research Grants Committee. In 1976, he was a member of the special Advisory Group on the Australian Science and Technology Council and became a member of the Interim ASTEC. In April 1977, he became Chairman of the permanent ASTEC. He retains a Research Professorship at the University of Adelaide.

INTRODUCTION

In the early period of European settlement in Australia, science policy was dominated by the need to improve agricultural yields, to develop good communications and transport, and to profit from the mineral resources. The colonial Governments were therefore quick to establish departments of agriculture and, in the latter part of the 19th century, developed an extensive railway system, albeit using a variety of gauges. A little later, similar pragmatic considerations led to intense experimental and developmental activity in wireless and in aeronautics.

The scientific and technological achievements in this early colonial period are particularly relevant to UNCSTD, but can be mentioned only briefly in this paper. In agriculture, William Farrer produced a new wheat variety, Federation, which provided high yields under Australian conditions, and Samuel Prior made a similar advance with barley (Prior's Chevalier). A.W. Howard was sufficiently astute to realise the potential of subterranean clover as a fodder plant as early as 1889. Significant advances in agricultural machinery were made by Australians even earlier: John Ridley developed the stripper in 1842, and more than 30 years later R.B. Smith developed perhaps the most famous of Australian agricultural implements, the stump-jump plough; the combine harvester was introduced by H.V. McKay in 1884. In mining, the most significant achievement was the development of the flotation separation process in the early part of this century. This resulted from the need to be able to separate economically the sulphide ores found at Broken Hill, but the process has since revolutionised mineral processing throughout the world.

These innovations were stimulated by necessity. Universities, technical colleges, museums, herbaria, astronomical observatories and meteorological observatories were likewise found to be a necessity and the colonial Governments moved to establish them.

The Commonwealth of Australia, with a federal system of government, came into being on 1 January 1901. The possibility of collaboration and cooperation between the States in agriculture, and in other areas, had been mooted some years before. With the new Constitution, it seemed that this would be facilitated and that the Commonwealth Government could itself take some initiatives in science and technology. Nevertheless it was some years before this was achieved.

Early Commonwealth Government involvement in science and technology centred on defence, and it was not until 1926 that the Council for Scientific and Industrial Research (CSIR) was established. CSIR concentrated its attention on the problems of agriculture and forestry and it was not until World War II that its activities were significantly extended to research and development (R&D) in support of the secondary industries.

In 1949, CSIR became the Commonwealth Scientific and Industrial Research Organization (CSIRO) and, during the 'fifties and 'sixties, rapidly expanded. It now employs over 7000 scientists and support staff. In that same period, there was also a rapid expansion in science and technology effort in other government agencies, and in the universities and colleges. The major government agencies, other than CSIRO, are:

- the Defence Science and Technology Organisation (DSTO), with a number of separate establishments and a total staff of about 5200;
- the Australian Atomic Energy Commission (AAEC), established in 1953, and now having a staff of 1270;
- Telecom Australia, with approximately 650 staff engaged on R&D;
- the Bureau of Mineral Resources (BMR), with about 500 staff.

In the university sector, academic staff increased from approximately 3500 full-time members in 1960 to approximately 13 400 full-time equivalent academic staff in 1976. In the same period, there has also been a rapid expansion in research effort and the universities now contribute significantly to the national R&D effort.

THE RECENT PAST

The Economic Climate

Australia's activities, both domestically and on the international scene, have expanded rapidly over the past two decades. Exports, especially of agricultural products and minerals, have increased substantially. Markets for agricultural products used to be virtually guaranteed in the United Kingdom. The advent of the EEC brought about a dramatic change in this situation and caused many people to think carefully about the future of Australia's agricultural exports and, to some extent, about the commitment of the R&D resources that should be made to agriculture in the future. In the mining area, most exports have been of crude ores, with relatively little processing being carried out in Australia. As a result, R&D activities have been small, but an expansion in this area is now evident.

Until recently, inflation and wages were under control, unemployment was low, and Australian manufacturers could compete both domestically (with some tariff protection) and, to some extent, in the world export markets. This situation has changed over the last 10 years as strong Asian manufacturing capabilities with lower wage structures have grown and asserted themselves on the world market. Most Australian industrial organisations (many of which were multi-national subsidiaries) could produce goods at competitive rates using imported technology, but the recent combination of high wages in Australia and the many competitively priced imports from Asia, has forced Australian manufacturers to re-think their strategies. The initial reaction was to seek still higher tariff protection, but industry and Government now accept that this artificial situation cannot continue indefinitely and that action, including the improvement of the rate of introduction of new technologies into Australian industry, is needed.

R&D Activities

The climate for the expansion of R&D has been generally favourable over the last 20 years, but the growth rate has slowed markedly during the 'seventies. High inflation over this decade has contributed to the reluctance by industry to invest in R&D.

The CSIRO and DSTO, and to a lesser extent the AAEC, the BMR and the Bureau of Meteorology, have continued to expand and to dominate the Commonwealth's role in R&D. The universities have also expanded rapidly and a high proportion of Australia's basic research is now carried out in tertiary education institutions. Table 1 compares the distribution of R&D expenditure in Australia with that in some other OECD countries. The high proportion of R&D which is classified as 'basic research' results from the disproportionately small expenditure on R&D in the industrial sector and from the assumption that a proportion of academic salaries should be costed against 'basic research'.

In the industrial sector, Commonwealth Governments have, since 1967, provided funds to encourage industrial innovation by subsidising R&D. Although this is now a common feature in all advanced, Western nations, the rationale for such support, and the comparative effectiveness of different types of support mechanisms, are still the subject of speculation and conflicting opinion around the world.

In the event, however, the level of industrial R&D in Australia has substantially decreased since 1973. In the Project SCORE figures for 1973-74, industry provided 34% of the Gross Expenditure on R&D; preliminary figures for 1976-77 indicate that this has dropped to 19%.

Many of the larger organisations in Australia are subsidiaries of overseas companies and much of the technology used is imported by captive transferral from the parent companies. Even when such companies have substantial Australian shareholdings, this importation of technology still prevails. In the past, this captive transfer has operated efficiently and, in many instances, it is still the most economical method. However, in many subsidiary organisations, and particularly in indigenous Australian industries (where technology is usually obtained under licence), this approach is no longer viable.

The bulk of Australia's industrial R&D effort has been directed towards adaptation and extension of world-based demonstrated technology. The adaptation can be by a product or process, or by the introduction of a product into additional fields. There has been some invention and subsequent commercialisation in Australia, but it has usually been in areas where the local market is relatively large. Although some of this locally developed technology has been licensed overseas, very few companies earn substantial royalties; for example, in the chemical industry, only one company is earning royalties in excess of $1 million per year. In general, this adaptive role has developed as a result of the small scale of the Australian market since the high cost of R&D cannot be recovered from the Australian market alone.

TABLE 1

Proportion of the Total R&D Funds
for Different Types of Projects

Country	Year	Basic Research	Applied Research	Experimental Development
Australia	1973	28	37	35
France	1973	21	32	47
United Kingdom	1972	8	23	69
United States	1973	12	23	65

Source: OECD study of resources devoted to R&D by OECD member countries. International Statistical Year 1973. 5 Vols. Paris 1976. See vol. 5, p. 70-71.

ROLES

Commonwealth Government

The Commonwealth Government plays a particularly important role in science and technology because Australian taxpayers provide the funds for over 60% of the country's total expenditure on R&D and pays the salaries of about 70% of all R&D workers. In these circumstances it is reasonable, and generally accepted, that R&D supported by the community should be relevant to the aspirations of the community. The weight of this responsibility has increased in recent times as the community has begun to question the need for scientific research and the benefits of new technologies and, at the same time, actively to campaign for the redirection of scientific effort towards the needs of society. The Commonwealth Government is acting to encompass this responsibility and, at the same time, to set national policies and priorities and determine an overall balance between basic and applied research, development and technology, and provide organisation and structure to achieve this balance (including support for industry). In addition, the Commonwealth has to ensure that Australia maintains a level of commitment in international activities consistent with its international responsibilities, but taking into account the priorities of these involvements in relation to domestic interests and requirements. Finally, it is the Commonwealth's role to establish mechanisms for better interaction between R&D workers in different sectors; to ensure, for example, that industry is aware of what is being done in CSIRO and in universities (and to be aware of the potential that exists in these organisations) and to establish procedures whereby industry can more effectively utilise some of the government-supported effort in solving its several problems, both long term and short term.

The States

The roles of the States in R&D is primarily to support extension and development (particularly in energy, agriculture, and mining) and to foster and carry out applied research specifically aimed at supporting each State's interests and responsibilities. The States also have responsibilities in regard to health, housing and the provision of general services (e.g. sewerage) and carrying out R&D to support these activities.

SCIENCE POLICY

Scientific research and development is no longer only an aid to the implementation of government policy, but is making an increasing contribution to the formulation of policy. This is 'science for policy' and complements a common understanding of the term science policy, which is often understood to mean the encouragement and support of science and technology - the creation of conditions to foster a high standard of R&D.

Throughout the world, Governments are becoming more aware of the role of science and technology in policy formulation. In Australia, the Government has increasingly sought advice from scientists and technologists when formulating new policies. Recent examples include policy and strategy formulation for energy, the mining and export of uranium, and the problems associated with managing the recently declared 200 mile Exclusive Economic Zone (EEZ). The forecasting of impending problems and crises, or of potential future benefits, is another area where the Government (through its scientific advisers) must be conscious of policy issues which will arise in the future. A current issue, for example, is the impact of computers on employment, a problem that was foreshadowed some 20 years ago, but about which Governments have been slow to take significant action.

ASTEC

The Commonwealth Government is aware of the need to be advised on science policy. The recent establishment of the Australian Science and Technology Council (ASTEC), and the decision of the Government that this Council should report direct to the Prime Minister, clearly indicate the importance that the Government places on the role that science and technology will play in policy formulation in the future. The functions of this Council are to investigate and furnish information and advice to the Commonwealth Government on all matters relating to science and technology, including: the advancement of scientific knowledge; the development and application of science and technology in relation to the furtherance of the national well-being; the adequacy, effectiveness and overall balance of scientific and technological activities in Australia; the identification and support of new ideas in science and technology likely to be of national importance; the practical development and application of scientific discoveries; the fostering of scientific and technological innovation in industry; and the means of improving efficiency in the use of resources by the application of science and technology. These terms of reference and the modus operandi of ASTEC will permit it to advise the Government on all matters pertaining not only to the fostering of science and technology but also to policy formulation. ASTEC is therefore able to provide scientific inputs to Government to complement the (often short-term) economically oriented inputs that originate elsewhere.

In order to establish a base from which coordinated policies could be developed in the future, ASTEC embarked on a broad-scale review of science and technology in Australia. This examined existing policies, activities, strengths and weaknesses, especially in research and development. As the review progressed, ASTEC was able to develop recommendations in relation to some of the problems which were identified, some calling for specific action on the part of Government and others outlining further necessary studies. Part of the resulting report was published in September 1978 as Volume 1A of 'Science and Technology in Australia 1977-78'. The remaining parts of this report (Volumes 1B and 2) were tabled in Parliament in March 1979. This review illustrates one way in which ASTEC, on its own initiative, identifies and offers advice on problem areas requiring Government action.

A second mechanism operates when the Prime Minister wishes to seek the advice of ASTEC on a specific subject. Since its establishment in April 1977 ASTEC has provided the following Reports for the Prime Minister in response to specific requests:

Energy Research and Development in Australia;

The Bureau of Mineral Resources, Geology and Geophysics (BMR); and a Supplementary Report; and

The Direct Funding of Basic Research.

Brief reports have also been made on the Report of the Independent Inquiry into the CSIRO and on the Report of the Committee of Inquiry into the Bureau of Meteorology.

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The third way in which ASTEC functions is by advising the Prime Minister on departmental initiatives in science and technology. Departments and agencies which are developing proposals on matters involving science and technology often consult ASTEC informally. From its strategic position ASTEC is able to provide the sponsoring agency with a broad national overview. When a submission is ready for the Cabinet and the decision is to be taken, ASTEC is able to provide advice direct to the Prime Minister. In this way the Government obtains advice on relative priorities. This ability to influence the machinery of government directly is a very significant difference between ASTEC and advisory bodies in some other countries. In many instances such advisory bodies are unable to influence day-to-day decisions by their Governments.

ASTEC is concerned to develop a consistent basis of advice and an ability to determine priorities. It is seeking to establish a framework within which to assess priorities; it will need to develop a system for measuring the level of activity and the contribution of science and technology; and it will need to make a conscious assessment of the relevance to science and technology of government policies.

Other Advisory Committees

Other, more specialised, advisory bodies have also been established. These include the National Energy Advisory Committee (NEAC) and the National Energy Research Development and Demonstration Council (NERDDC); the Commonwealth Rural Research and Extension Council (CRREC); the Astronomy Advisory Committee; and the Australian Marine Sciences and Technologies Advisory Committee (AMSTAC).

PRESENT SITUATION AND PROBLEMS IN THE ALLOCATION OF RESOURCES

Commonwealth Activities

The increased demands for accountability of expenditure in science and technology, together with the world-wide recession, have led the Government to review the organisation, functions and operations of most of the major scientific organisations under its control. The most important such review was the Independent Inquiry into the CSIRO, which was completed in 1977. The Bureau of Meteorology was subjected to a similar examination, and the Bureau of Mineral Resources has been examined by a review committee and, subsequently, by ASTEC. A review of the research functions and activities of the Australian Atomic Energy Commission has just commenced. It is reasonable to expect that other major establishments will be put under the microscope in the near future.

In education, a major review is nearing completion. The recommendations contained in this report are expected to have a significant effect on universities and colleges in the future, and on their research activities. Moreover, ASTEC was requested to examine the level of and arrangements for the direct funding of basic research in Australia, and the report has been forwarded to the Government.

Most of the fundamental research in Australia is carried out in universities and the recommendations of this report could therefore have long-term implications for the future of university research in Australia. ASTEC firmly believes that curiosity-motivated fundamental research needs to be fostered: it is this work which provides the foundation for the applied research and innovations leading to new products and processes, even new industries, to meet the needs of future generations. ASTEC believes that there is a need, in Australian universities, to encourage large (sometimes multi-disciplinary) research groups and teams; the fragmented one- and two-man efforts which prevail at present seldom compete with the concentrated effort provided by large research teams overseas.

One way of achieving this would be to establish specialist advisory committees in important areas and to charge these bodies with the responsibility of allocating funds within particular areas. The National Energy Research Development and Demonstration Council (NERDDC) is such a body, allocating funds for energy research. NERDDC will doubtless aim to achieve a balance between short- and long-term research, development work and demonstration projects. AMSTAC is another such body; it is soon to be established, as a standing committee of ASTEC, to advise on priorities and the allocation of resources in marine science and technologies. In view of Australia's additional responsibilities as a result of the declaration of the 200 mile EEZ, the establishment of AMSTAC to coordinate activities is expected to benefit Australia in many ways. ASTEC proposes to identify other priority areas from time to time.

ASTEC has also supported the concept of Centres of Concentration propounded in the Sixth Report (1975) of the Universities Commission.

INDUSTRIAL R&D

The manufacturing industry sector is an important component of the Australian economy. It accounts for approximately one-fifth of total employment, of gross domestic production, and of exports. The level of R&D activity in the industry, providing the technological base for this sector, reached a peak about 1973, but has substantially declined since then. As the long-term survival of manufacturing in Australia requires a high level of modern technology, and of technological innovation, and as ASTEC believes that the level of R&D effort even in 1973 was inadequate, this recent trend is a cause for concern. ASTEC has made several recommendations designed to support industrial R&D.

Government Incentives for Industrial R&D

Commonwealth Governments have recognised the need for an increased level of industrial R&D and have introduced legislation in attempts to provide incentives. The Industrial Research and Development Grants Act 1967-73 provided for the payment by the Commonwealth Government of grants to companies in respect of increased expenditure on R&D over that in the base year. This Act had several useful features. For example, it required the company to employ full-time a professionally qualified person (or a non-professional person whose qualifications were acceptable to the Board) to supervise the R&D. This requirement initially led to an increase in the number of professional persons working on R&D. Moreover, many of the companies assisted by grants began to undertake R&D for the first time. On the other hand, the general grants were made without any reference to the merit of the projects, presumably on the assumption that all research should be encouraged regardless of its quality.

In 1976, this incentives scheme was replaced by a system which provided for the payment of Commencement Grants and Project Grants. Commencement Grants are intended to encourage companies whose R&D activities are either non-existent or at an infant stage to establish or develop a basic capability in industrial research and development. Project Grants are intended to support specific projects proposed by companies, and assessed by the Board. The Board makes its assessment by taking into account the technical and commercial merits of each project, the capabilities and resources of the company to undertake, or have undertaken, the required R&D, the ability of the company to exploit commercially the results of the project and, finally, the need by the company for the financial assistance.

Other changes (and a substantial increase in the overall level of funding to some $25 million) were made in mid-1978. There is a need to examine more broadly the ways in which government measures can be used to influence the process of industrial innovation.

Possible Changes

There is also a need for decisions on the industries which should be assisted, as the provision of assistance to all will not promote the specialisation that many believe to be needed if Australian industry is to survive in the international market-place.

Proposals for encouraging industrial R&D which need further examination include:

(i) Tax incentives. Incentives for R&D in the form of deductions exceeding 100% of the expenditure incurred in R&D have been introduced as experimental measures in several countries overseas, including Canada, Sweden and the Federal Republic of Germany. There are several ways in which tax incentives could be introduced, but the basic advantage is that companies can calculate, at the outset, what the return will be.

(ii) Contracting to industry. The concept of Government contracting R&D to industry on a large scale has been practised widely overseas, but to only a limited extent in Australia. The reason for developing such a practice is that it encourages industry to build up its R&D capacity; the availability of that capacity is then an encouragement to industry to conduct more R&D itself. At the same time, the contracting process encourages technology transfer through substantial ongoing research activities within the industrial sector. Although arguments of national security are often invoked when the question of contracting to industry arises, it should be pointed out that overseas countries have successfully contracted sensitive research (e.g. defence work) to industry.

(iii) Research associations. Research associations provide a means by which small companies which cannot undertake R&D can make use of facilities provided cooperatively, usually on an industry-wide basis. They take various forms and they may be funded wholly or partly by Government, by fees, or by industry levies.

In Australia, research associations which receive government support have been largely associated with and dependent upon the CSIRO. Their position was examined by the Independent Inquiry into the CSIRO and several recommendations were made. ASTEC has expressed its support for research associations as a means of encouraging innovation in small firms.

There is considerable overseas experience which could be drawn upon in any further examination of research associations. The United Kingdom, and most European countries, have had associations of this type for many years and there is sufficient diversity in their functions, and in the methods used to support them, for a wide range of comparisons to be made. Comparisons could also be drawn with university companies now being established in the United Kingdom and Canada and with the activities of companies such as Unisearch and Technisearch in Australia.

(iv) A Research Development Corporation. Many countries, following the lead given by the United Kingdom, have now established National Research Development Corporations. Such bodies promote the development by industry of new products and processes which have been invented in government laboratories, in tertiary educational establishments, and in industry itself. They advance money where necessary to bring inventions to the commercially viable stage. There is no

Research Development Corporation in Australia at present, but the possibility of establishing one is under examination.

NATIONAL FACILITIES

Many major advances in science and technology have been achieved with simple and inexpensive equipment, but it must be admitted that most of these were in the eighteenth and nineteenth centuries. Major discoveries can still be made with simple equipment but, in some fields of endeavour, significant research and development is simply not possible without the use of expensive equipment or special facilities, for example, optical and radio telescopes, an ocean-going research vessel, a primate colony for medical research or a high-security animal health laboratory. Private and government funds are never unlimited, and it is necessary to consider which proposals have highest priority and, after the facilities are established, to ensure that the best use is made of them.

There is, therefore, a strong need to provide some mechanism for the funding of expensive facilities after a suitable evaluation of proposals and to devise procedures to ensure maximum use of any such resources, particularly by university, college and industry investigators, and by private research institutes. There is a need for proposals to be subjected to peer-evaluation and, where the facility is not used full-time by one laboratory, for administrative procedures to ensure that expensive resources will be available to other qualified investigators.

In Australia at present there are a few examples of what might conveniently be termed national or regional facilities. These include the Anglo-Australian Telescope, the Australian National Radio Astronomy Observatory, the National Nuclear Magnetic Resonance Centre, and the facilities and services provided by the Australian Institute of Nuclear Science and Engineering. These examples illustrate how effective the concept of national facilities can be.

WORKSHOP DISCUSSION

POLITICAL, ADMINISTRATIVE AND POLICY ASPECTS OF SCIENCE AND TECHNOLOGY

REPORTER

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Within the objectives of the Workshop, this theme was seen as being most usefully explored through a focus on Australian experience, with the aim of drawing from it relevant insights for the developing countries. The theme was treated under seven distinct headings.

1. THE HISTORICAL PATTERN OF ALLOCATION OF RESOURCES

In brief, scientific and technological resources have traditionally been highly concentrated in Australia. In terms of performers, R&D has been conducted predominantly in government institutions, particularly CSIRO, with relatively low levels in both universities and industry until the past few years. In terms of area, there has been a considerable emphasis on agricultural and related biological research.

The pattern of institutional development reflects these priorities. CSIRO (then CSIR) was modelled directly on the British DSIR, which was established during World War I in recognition of Germany's technological superiority. In Australia, where the needs were economic rather than military, efforts were concentrated on rural commodities, and, with the incentive of the Empire Imperial Preference, the focus of the research was agricultural products and processes. The Radio Research Board was established originally to determine the appropriate siting of radio transmitters. During World War II, the National Standards Laboratory was set up within CSIRO out of a recognition, in its simplest terms, that 'nuts made in one factory would not fit bolts made in another'. Post-war developments include: the Weapons Research Establishment, the CSIRO Divisions related to secondary industries, the Atomic Energy Authority and the major growth of research in universities. All of these institutional developments can be seen as a consequence of political decisions to develop a scientific and technological capability in particular areas.

With respect to institutional operation, intervention has been relatively low-key, indirect and certainly not exposed to the demands of accountability currently becoming fashionable.

Conclusion: Politics and interpretation of national needs have had a strong influence on the structure and broad emphases of scientific research in Australia, though until recently there has been only relatively indirect influence on program content.

2. THE RELATIONSHIP BETWEEN MATURITY AND RESPONSIVENESS

Peres' argument that 'it is necessary for both science and politics to develop optimal degrees of sophistication before each can interact with the other to the national benefit', does not seem to be adequately justified. The evidence of the previous section, and of the close linking of agricultural research to practical needs from its earliest days in the 19th century, do not conform with a model of necessary separation. The Australian experience is that this isolation of science has existed only, and then to some extent, in universities and those CSIRO Divisions supposedly oriented to manufacturing industry. The value of the isolation has yet to be demonstrated.

Secondly, the experience of the developing countries in setting up science establishments protected from political pressures and national needs, as in India, has not been marked with great success. Even if the isolation model had a great deal of justification, political pressures would not permit its adoption. No developing country can sit back for 25 to 50 years to allow its scientific and technological capability to mature before demanding its application to pressing needs.

Conclusion: On the grounds of both experience and realism, there is no requirement that science establishments be excessively shielded from political pressures, though limitations of form of influence need to be recognised. The CSIRO model rested on a particular set of social and economic conditions and the pre-existence of a strong scientific culture. It is not appropriate for transposition unaltered to developing countries.

3. CENTRALIST VERSUS PLURALIST MODELS OF ALLOCATION

The categories of centralism and pluralism as models for national science policy systems or allocative mechanisms are of limited value. There are many strands to each of these models, including the degree of dispersion of authority, the extent of bureaucratic methods, the type of control exerted and the degree of involvement of both scientist and politicians, all of which are not necessarily connected with each other in any particular case.

There has been a general move towards pluralism in most industrialised countries. But what of the smaller countries with limited resources available? The former head of the Weizmann Institute, Professor Bergmann, wrote of Israel: 'Science and technology ... can only succeed if they are planned in a rational manner, which means a centralised manner ... new countries can only develop if they have centralised, long-term planning and if the plan is ... centrally supervised, at least for that time the country needs to arrive at economic stability and independence.' Different mixes may be necessary at different stages of development, in different scientific and technological areas, and because of different relationships of science and technology in different fields, times and places.

Beyond all these difficulties there is evidence that centralist and pluralist elements of a system can be symbiotic. In the UK the Rothschild 'customer-contractor' relationship was centrally determined within the Central Policy Review Staff. It was directed, however, in a pluralist manner, to government departments and its effect has been the considerable strengthening of scientific capability within these departments, particularly in its ability to identify its research needs.

Conclusion: Models for decision-making and allocation systems need to be carefully tailored to the particular structure, resources and needs in the broadest sense, of a country and of its different regions.

4. RESOURCE ALLOCATION MECHANISMS

The problem of developing an adequate basis for the allocation of resources is central to the effective use of scientific and technological resources in all countries.

The process of allocation in Australia, until recently, can be characterised as incremental and marginal, consisting largely of minor changes, usually increases, occasionally decreases, in funding level. That is, in essence, the past has defined the future. Recently there have been distinct moves towards a more sectoral, specific mission-oriented approach to allocation. This is signified most clearly by the establishment of the National Energy Research Development and Demonstration Council (NERDDC) for the funding of energy-related research, the Commonwealth Rural Research and Extension Council (CRREC) for rural research and the Industrial Research and Development Incentives (IRDI) Act for supporting R&D, essentially in industry. All those developments are seen as appropriate.

Another development has been that of a highly elaborate advisory system. The jewel in the crown is the Australian Science and Technology Council (ASTEC), charged with advising Government on scientific and technological matters. There is considerable potential for, and evidence of initial achievement of, a vital role in resource allocation and in major structural changes. Legislation establishing the Council and its membership reflects an inherited tradition of science and technology as central to these issues. While this is not a matter for dispute, the range of social and economic issues involved in 'science for policy' and the social implications of science and technology for development make it important that ASTEC should draw on expertise outside of its own membership, particularly that of social scientists, in dealing with these issues. Moreover, in pursuit of political influence it should not neglect its very special position to consider long-term issues.

There has also been a proliferation of more specialist advisory committees, including the Australian Marine Science and Technology Advisory Committee (AMSTAC), the Antarctic Research Policy Advisory Committee (ARPAC), the Australian Institute of Marine Science (AIMS) Advisory Council and the Observatory Advisory Committee. These play a useful role, not only in their advisory function but also as a channel of information flow. The greatest weakness is that membership of these committees may become restricted to a small group of professionals who can become pseudo-bureaucrats, serving no interests other than their own.

Conclusion: The emerging sectoral basis of funding, and the highly elaborate advisory structures, constitute a very effective allocative mechanism for an industrialised country like Australia. However, this experience is of strictly limited value to the developing countries. There is a great danger that they will seize on the model of ASTEC without perceiving the enormous number and variety of sources of support, and of checks, which contribute vitally to its effective operation.

5. INSTITUTIONAL RIGIDITY

Setting aside allocative mechanisms, the greatest limitation to changing the allocation and application of resources is rigidity of institutions. This rigidity is partly a consequence of reliance on marginalist policies, which prevents the redistribution of resources, without the greatest difficulty, from one sector of performance to another. There are also very real difficulties in shifting the mission of a research establishment from one area to another. The difficulties experienced with the loss of mission of AAEC in 1972 and the closure of Woomera are clear evidence of this. We are currently experiencing a major round of inquiries of our major research institutions. This is salutary, but its *ad hoc* nature limits the possibility of an overall view. There is a need to establish a basis for continual and evolutionary review - an in-built assessment procedure which does not require political pressure for its instigation. Models are offered by the French Council for National Scientific Research (CNRS), which automatically closes Divisions after 30 years, the German Max Planck Institutes, which are built around an outstanding scientist and dismantled on his departure, and the so-called 'sunset legislation', limiting the period of operation of laws.

Another feature of rigidity is the lack of mobility of individuals between organisations. There have been numerous inquiries into ways of promoting this mobility, and schemes established to provide it. All have been remarkably unsuccessful. Past decisions seriously limit the possibility of dramatic change in Australia. Differing conditions of employment, superannuation and promotion rights all operate against mobility. However, the problems are sufficiently clearly established for developing countries to profit greatly from Australian experience.

Conclusion: Australian experience of the causes and effects of institutional rigidity could provide a very useful lesson for developing countries in controlling and redirecting their major scientific and technological institutions and in establishing conditions for the maximum opportunities for the mobility of staff.

6. UNIVERSITY RESEARCH

The major source of funds for university research is the Tertiary Education Commission (TEC), and with the dramatic growth in student numbers over the past decade there has been a great increase in both the level of funding and the number of researchers receiving it. This growth has not been accompanied by a reconsideration of the purposes of university research, the vast majority of which remains fundamental. On grounds of national need, of competence of researchers and of accountability for funds, there is a case for some re-allocation towards more mission-oriented research.

Relatively simple means for achieving this shift are by either earmarking a certain proportion of the funds of both the Australian Research Grants Committee (ARGC) and TEC for mission-oriented research, or establishing a separate funding body for this purpose. It would be necessary to ensure that recognition for this research, in terms of tenure and promotion, be no less than that for pure research. These, and other means, can also be adopted to make the research facilities of universities available to outside organisations and individuals.

Conclusion: The university research sector has reached a size where it is no longer appropriate for its scientific research to be predominantly fundamental. Developing countries should not be misled into equating exellence only with pure research, and should link the research directions in the universities to areas of national need.

7. PUBLIC PARTICIPATION

A number of steps towards increasing public participation have been taken, through the publication of discussion papers ('Green Papers') and the number of recent Commissions of Inquiry. The issue of lay membership should be further examined, though it is recognised that this will allow representation only to an articulate minority. The majority of the public will only be reached by better publicity and encouragement of discussion of issues raised by science and technology.

Conclusion: A wider involvement of the public in issues with a scientific and technological component would seem to both offer advantages and be politically necessary. Without a well-developed infrastructure, however, such involvement could merely hinder all advances.

THEME 2

THE IMPACT OF SCIENCE AND TECHNOLOGY ON SOCIETY AND ON INDIVIDUALS

INTENDED AND UNINTENDED CONSEQUENCES

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INTRODUCTION

Professor Jarrett attempts to establish a framework in which the potential contribution of science and technology to economic development can be discussed. Since, presumably, the United Nations Conference on Science and Technology for Development in August 1979 is directed, in the main, at Third World countries, his paper proceeds to discuss the various dimensions of economic development. Professor Jarrett presents three possible models for the development process and, depending on one's preference amongst these models, there will be a consequential set of values with respect to the role of science and technology.

For an economist, the question of economic development revolves around the twin objectives of economic growth and reduction in inequality of income distribution. Quoting from a wide variety of agricultural innovations in Third World countries, Professor Jarrett discusses the intended and unintended consequences. He presents evidence that the primary effects have brought along with them secondary effects which have never been intended. Such secondary effects have involved the displacement of tenants, the destruction of social relationships in traditional societies, and the disadvantaging of particular groups, for example, women, in traditional societies.

Innovations by their very nature will disrupt the whole complex of economic, social and political relationships in any community. If the political will exists and the necessary institutions also exist, it is possible for the gainers from technological change to compensate the losers. In many developing countries, however, neither the political will nor the institutions to effect the compensation exist. Professor Jarrett concludes by suggesting a possible framework, the Sabato triangle, within which innovation can be discussed.

Technical change is one of the key defining characteristics of modern industrial society. It cannot however be isolated from the social and economic context in which it arises, and which, in turn it affects. In modern society, as in traditional society, the production techniques and technologies are fundamentally interdependent with social and economic structure, culture, and 'world views' and 'theories' in the 'common stock of knowledge' of the society. Change in techniques can therefore cause change throughout the whole social fabric.

Modern industrial society has been characterised by a continuing stream of changes in production technologies, partly stimulated by scientific research and partly by economic 'need' recognised within industry. The net effect has been a massive transformation of world society over the last 200 years - with, for example, the rapid urbanisation of man - with its consequent benefits and disbenefits, the growth of very large scale business, and growth and dissipation of economic sectors which have led the path of industrialisation.

THEME 2 - Introduction

Particular technological innovations have clearly played a dominant role in this social transformation, for example, processing of petrochemicals the automobile, the 'pill', the computer. However, Professor Hill suggests that it is worth looking beyond particular cases to patterns of technological change - to 'bunchings' of innovations that occur at much the same time, which connect new materials, processes, products, energy supplies and economic and social opportunities, and have the most diffuse and dominant impact on social transformation, economic development and employment. Relying on a refurbished view of Kondratiev long cycles of development, Professor Hill suggests that there have been four such cycles since the advent of industrialisation related to technological developments associated with - textiles/steam/iron; railways/steel/coal; electricity/the chemicals industry; the internal combustion engine/plastics/electronics and the use of oil and natural gas. He then argues that we may be facing the end of a fourth Kontratiev long cycle, with associated downturns in economic activity and employment. As a consequence we must look towards what future cycle is likely to be upon us. The most pervasive and radical technological changes are presently those associated with microelectronics. This case is reviewed in terms of both similarities and differences of these 'bunched' innovations to those which have characterised previous long cycles of economic and social development. The conclusion follows that microelectronics does promise a future diffuse impact on the whole society but that, within a resource- and energy-scarce environment, it may cause significant social disruption, particularly with respect to unemployment. Its application is mediated by the organisational structures of industry - with 'bigness', 'multi-faceted' business, and 'science-based' criteria predominating - that we have inherited from previous long cycles of development. This organisation character is likely to lead the direction of impact of microprocessors in the future.

Professor Hill concludes that there are two alternative futures for developed countries, and in particular, Australia. One involves allowing development to follow its own path, and promises social disruption. The other involves intervention, planned social and industrial change, and a particular role for scientific and technological knowledge generation and use.

Dr Millington places emphasis on the growth in population since the Neolithic agricultural revolution as it has probably been the major stimulus toward the development of technology. It is population growth itself which has had the greatest ecological impact, resulting in increasing intraspecific competition for resources for individual survival. Increasing interspecific competition between man and the flora and fauna of the biosphere is similarly evident and inevitable.

As population has increased, the demand for foodstuffs has exceeded the rate of supply from natural plant communities, as has the demand for materials and energy from low-grade sources. Dr Millington couples increasing lack of self-sufficiency to individual dependence on complex institutional and productive systems whose structures lack the characteristics of stable ecosystems.

The impact of technology is measured for both energy and materials transformation by comparing anthropogenic rates with those occurring in natural systems.

The nature of limits is discussed by Dr Millington in terms of rates of energy or mass flows, as well as limits due to inadequate knowledge of the control systems or the coordination necessary for human activities.

Dr Millington stresses the importance of science in providing the framework of principles within which must be found the solutions to ecological problems arising from coupled growth in technology and in population.

Dr Hetzel reviews the impact of science and technology on health by considering the improvement of health in Australia since 1880 up to the present time. He attributes the reduction in infant mortality mainly to better education and nutrition, with control of the physical environment (water and food supply and housing) also playing a part.

In Papua New Guinea rapid improvement of health has been achieved since 1945, and has been associated with a fall in infant mortality and simple treatment measures carried out at village level. However, life-style factors are now, as in Australia, becoming important.

The Aboriginal people in Australia demonstrate vividly the lag which can exist in the application of knowledge of science and technology. Aboriginal infant mortality remains much higher than in the white Australian population and is associated with poor nutrition, poor control of the environment and inadequate education.

This gap between knowledge and its application is also apparent in Australia as a whole. Dr Hetzel sees the improvement of health as depending on a social process involving the dissemination of scientific and technological data, its discussion by the community and then appropriate political initiative followed by implementation and evaluation. This process often fails to occur because of inadequate dissemination of information and education and much more effort is required in this area to realise the gains from advances in science and technology applied to health improvement.

The discussions highlighted the need to study and monitor the economic and social effects of new technology, since society can only influence the impact of science and technology if it is aware of the consequences of its introduction.

Discussion on the effects of transfer of technology to developing countries brought out the important role that Australia has played in providing technical assistance. Australia should not refuse to supply technology on the grounds of possible social and economic consequences. Rather, developing countries should improve their basic education and technical training to enable appropriate choices of foreign technology to be made.

However, developed countries should offer recommendations on how to mitigate the bad effects of a new technology, where they had already been recognised, before it was introduced. The syndicate found that multi-national corporations have made a positive contribution to the economic and social development of many developing countries through the technology which they have introduced.

A framework for the development transfer process was suggested and a number of firm conclusions were reached covering the proposal stage, the evaluation stage, the implementation stage and the review stage. Because the second syndicate concentrated on the practical aspects of managing the development transfer process, they made a number of specific proposals for government action. They proposed the implementation of the Environment Protection (Impact of Proposals) Act for all large development transfer programs. Also proposed was the creation of a small-projects division of ADAB which should be funded separately. The final proposal looks to Australia providing funds for setting up more independent advisory teams.

TECHNOLOGICAL CHANGE - CREATOR OR DESTROYER?

BY

FRANK G. JARRETT

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Professor Jarrett worked in Indonesia for 3 years, 1945-48, and in Pakistan for 18 months, 1967-1969, as a member of Harvard University Development Advisory Service. He served as Consultant to the Department of Agriculture, Stock and Fisheries, Papua New Guinea, and to the University of Papua New Guinea in 1972.

He was a member of the CSIRO Wool Research Advisory Committee (Weickhardt Committee) in 1971.

His current research interests are on the generation and diffusion of agricultural innovation.

INTRODUCTION

Various countries are preparing national papers on science and technology for development as part of the preparations for the United Nations Conference on Science and Technology for Development. Presumably these national papers are to provide some guidance and information for the countries concerned as well as the Third World countries. Since the bulk of the world's scientific and technological resources are located in the developed countries, it is these same countries which found it easier to prepare their national papers and, potentially, it is these same countries who will come to play a major, if not a dominant, role in the proposed 1979 Conference. And yet a fundamental question one has to ask is whether the science and technology which is generated in the developed countries is transferrable to Third World countries for their benefit. The social, political and economic environments in which the science and technology are to be embedded are distressingly complex and distressingly different from those which pertain in the developed world. It is perhaps understandable for scientists and technologists to regard themselves as major contributors to economic growth in the developed world - a proposition about which there has been considerable debate (see Boylan's[1] survey) - and to extrapolate this experience to Third World countries. That science and technology has been cast in the role of St. George is epitomised in the statement by Nehru[2] in 1958 when he said 'I do not see any way out of our vicious circle of poverty except by using the new sources of power which science has placed at our disposal.' The image of 'destroyer' of the 'poverty dragon' has become somewhat tarnished 20 years after the event. The optimistic prediction by politicians, scientists and technologists that this 'white knight' would banish poverty from the face of the earth has simply not eventuated.

In fact, a contrary view has grown up which is antagonistic towards science and technology from developed countries. The Indian economist, S.L. Parmar.[3] cautions the poorer countries of the Third World against relationships with the developed countries which will draw the Third World closer into the network of international relationships, including the scientific and technological. He says: 'While the benefits of their prosperity do not easily flow towards us, a spill-over of their adversities tends to impose disproportionately heavy burdens on our economies.' In Parmar's view, this spill-over from the developed world manifests itself in increased unemployment, in increased inequity in the distribution of income, in increased scientific and technological dependence on the developed countries, in the frustration of indigenous innovation, in consumption patterns based on a rich elite with essentially Western modes of behaviour, and in the over-specification of many producer goods (e.g. roads, machinery). This basic dichotomy between science and technology as 'saviour' and science and technology as 'destroyer' is, of course, a polarisation of views, but it does highlight what I regard as one of the basic conflicts which will have to be resolved if, in fact, the 1979 Conference is to be translated into operational programs for the Third World countries.

WHAT IS DEVELOPMENT?

The key words in the 1979 Conference are three: these are science, technology, development. Others can delineate the areas of science and argue how science is translated into technologies. The economist tends to encapsulate science and technology in the notion of innovations or technological change. The impact on the economy of both science and technology is only felt when the new knowledge generated by science and technology is actually incorporated into the way that commodities are produced (process innovations) or into the development of new products (commodity innovations). My concern is not so much with the generation of the innovations, but, primarily, with what the contribution of these innovations to development is likely to be. This brings me face to face with the problem of defining what development is. It is impossible to avoid this confrontation, since it is implicit in the title of the 1979 Conference that development is desirable and that science and technology have some contribution to make to this development.

Development is clearly a multi-dimensional concept and what is regarded as development will depend to a large extent on one's value system. Clearly, development can refer to the totality of social and economic changes which can occur in the particular directions that are regarded, by someone, as desirable. Marshall Wolfe[4] has postulated three basic images for development. The preferred image will influence the measures which are taken to achieve this preferred image and will affect the policies that might be adopted with respect to how science and technology might assist in achieving the preferred image.

Wolfe's first image is essentially a 'gap model', which sees nations as distributed along a spectrum. The developed countries with high living standards and relative equality in the distribution of incomes are at one end, with the poorest nations often with gross inequities in income distribution at the other. In between there are a series of gaps as the countries are ordered from the richest to the poorest. Development is then viewed as a continuous struggle by countries to move from the bottom end of the spectrum to a position closer to the top end.

Wolfe's second image might be called the 'pyramid model', with individual countries, individual groups and particular interests at the apex. They rest on the broad base of the poorer majorities and maintain their position at the top through the exploitation of these majorities. The conservatives would regard this situation as a natural ordering while the revolutionaries would be concerned with, at the very least, altering the pyramid more to a rectangle. Development, in this context, for the conservative is the maintenance of the status quo, but with a trickle down to the masses at the base from improvements which occur at the top. For the radicals, this trickle-down effect is totally unacceptable and development is seen largely as a political process resting on revolutionary action to alter existing power structures.

Wolfe's third image is essentially apocalyptic and sees the development process as leading to disaster. The ecosystem is destroyed as population increases beyond bounds, and natural resources, particularly those which are non-renewable, are used up in the process of development. This model clearly emerged in the Meadows[5] and Forrester[6] books. In the first two models, development was regarded as desirable, although there was disagreement as to who were the beneficiaries of development. In the last model, development is of course regarded as a 'bad' and the attitudes which one will take towards science and technology in the model will be quite different from the attitudes that one would take if one were to adopt either of the first two models.

Essentially then, the question of development will depend on value judgments as to what is a good or better society. As an economist, I have to delineate the problem of development so that it is amenable to some sort of economic discussion and I leave it to others to place their own construction on what development is all about. Although economics has traditionally been labelled 'the dismal science', most economists would not agree with the gloomy prognostications which are contained in Wolfe's third image. Economists would in general argue that economic development does involve improvements in material standards of living, but at the same time they would argue that the manner in which these benefits are obtained and distributed is also important. In a nutshell, to many economists, development is all about economic growth and the distribution of the benefits arising from such growth. However, this must be tempered by the question of the mode in which such growth and distribution take place. It may be possible to achieve these development targets of the economist, but only under a political organisation which is the antithesis of other values; for example, freedom of choice. I leave it to the political scientists to comment on this dimension of development. Alternatively, it may be possible to achieve these goals by relying heavily on imported science and technology, but this mode may be unacceptable if it creates a neo-colonial scientific and technological dependence.

In the terms of reference that an economist adopts, the twin development goals have been usually those of economic growth and equity in the distribution of income. It is probably true to say that economists once tended to emphasise economic growth and the need for an efficient resource allocation to achieve this growth and tended to de-emphasise the problems of equity. It was often argued that provided the allocation of resources was 'right', other institutions could be used to redistribute the income achieved amongst the deserving members of society. In more recent years, the recognition that development is essentially dynamic has meant that problems of static resource efficiency have become less emphasised while problems in reaching the poorest members of the community with development programs have been pushed to the fore. As part of that process of reaching the target-poor, the question of their level of employment has become pre-eminent.

In the conventional strategy which emphasised economic growth, it was hoped that as economic growth occurred - even though it may have benefited the minority well-to-do - there would be a trickle-down effect so that, in the long term, the benefits of economic development would be widely transfused throughout society. The fact that in many developing countries institutions simply did not exist to facilitate this transfusion was ignored. The nett result was that no, or, at best, very little, trickle-down occurred and most development did little to alleviate the mass poverty and unemployment which characterised the poor in both urban and rural areas of Third World countries. In part, this distributive effect was often associated with relatively rapid development in the modern sector of the economy and often this development occurred at the expense of the traditional rural and urban sectors. In more recent times, this equity objective has been translated into a target of fulfilling basic needs with the associated elimination of poverty and unemployment. The science and technology role is essentially one of developing technologies which best meet this basic-needs objective. In developing countries the rural poor are numerically greatest, given the relative dominance of agriculture, and are found particularly in the landless agricultural labourers. Scientific and technological knowledge, if it is to be put to best use in reaching these target groups, will have to acknowledge that they are in fact the target groups.

In my view, the fundamental question confronting scientists and technologists is whether their skills and knowledge can be directed at improving the lot of the rural and urban poor. Even if they are unable directly to increase the level of employment, the innovations which are transferred from developed countries should not exacerbate the existing levels of poverty and unemployment. However, it is seldom the case that the innovations are universally damaging to everyone in the society. In fact, it is almost a truism to say that the adoption of innovations will benefit, at least in the short run, the early adopter but worsen relatively, or indeed absolutely, the position of the non-adopters. The classic case in recent years has been the advent of the high-yielding varieties of crops - mainly wheat and rice - under irrigation, and using fertilisers, pesticides and weedicides; the whole package being known as the Green Revolution.

There is no doubt that, in the context of many Third World countries, the Green Revolution benefited some of the rural community but made others relatively worse off. McInerney and Donaldson[7] suggest, for Pakistan, that when the Green Revolution technology package was associated with farm mechanisation, it led to large-scale displacement of tenants. Landlords chose to farm larger properties with the new technology. In the sample of farms studied, average farm size was 45 acres prior to the innovation and 109 acres thereafter. The same displacement of tenants is noted by Cohen[8] in Ethiopia with the Chilalo Agricultural Development Unit (CADU), even though the machinery involved was already familiar to farmers - ploughs, oxcarts, simple harrows and threshers rather than tractors and trucks. 'The eviction problem is proportional to the amount of land suitable for mechanisation...since CADU's arrival an enormous number of tenant households have been evicted... In 1972, the best estimates placed evictions at about 5000 tenant households since 1966.' The same displacement of tenants does not seem to have occurred in the Indian Punjab, where there was a greater protection afforded to tenants in the face of the new technology. If anything, the available evidence suggests that there were increased employment opportunities in the Indian Punjab and that agricultural wage rates in real terms materially increased.

Nevertheless, the distribution of wealth is substantially altered by technological change. Since land is the major asset holding of farmers, and because it is in inelastic supply, much of the gains from technological change in agriculture tend ultimately to be reflected in increased land values, Ladejinsky[9] quotes land values in the Indian Punjab which rose from 2000, 3000 and 5000 Rupees per acre to 10 000, 12 000 and 15 000 Rupees per acre in the five years following on the Green Revolution. The State can, if the political will exists, use its fiscal powers to capture some of these windfall gains for redistribution to other less advantaged areas, or for other objectives which will promote development. However, such redistribution involves a set of institutions which may not be present. Clearly, some of the gains could be used to foster the development of technology specifically directed at small farmers or directed at innovations likely to absorb landless agricultural labourers.

In Java, prior to the Green Revolution, rice harvesting was traditionally done by women using a small knife. The shares in the harvest were determined by complex social structures based on social distance. Kinswomen got from one-fourth to one-half of the harvest amount, close neighbours one-sixth to one-eighth, and 'others' one-tenth to one-twenty-fifth. The improved rice varieties were followed by farmers cutting down on traditional obligations. The standing rice crop was sold to middlemen who drastically reduced the number of harvesters. In some cases these middlemen brought in men who harvested with a sickle and who were paid a cash wage.

THE ECONOMIC DYNAMICS OF TECHNOLOGICAL CHANGE

Changes in the Output Mix

I would argue that many attempts at promoting economic development in Third World countries have concentrated on one dimension of the system and have left the interlocking components to 'someone else'. For instance, agricultural scientists may see their role as one of operating on the science and technology lever. Operationally, this is often expressed as the apparently simple objective of increasing total food output without any further responsibility. The fact that the technologies that they develop require an infrastructure which is not present, complementary inputs which are not available, or that the technologies worsen the terms of trade and relative income position of agricultural small holders, is 'someone else's' reponsibility. It is hardly surprising that many well-meaning attempts at promoting development have not achieved their goals. Even the goals are often defined by external agents, be they the agricultural scientist with his objective of increases in physical output, the economist with his concern with efficiency and growth, or the political scientist with his alarm that the existing institutions reflect a power structure which is incompatible with his notions of egalitarianism.

Whether any of these objectives reflect the needs of the Third World countries is doubtful. It is in a distinctly Western scientific tradition to see things in a problem-solving, or means-ends framework, but this framework may be quite alien to traditional societies. Even when Western science has entered the educational system of developing countries, it is a common experience that students learn the principles but have difficulty applying them to solving agricultural problems. Speaking of Latin-America, Richardson[10] states: 'In general, the principles of botany, physiology, genetics, chemistry, physics, mathematics and other disciplines which are indispensable for practising the art of crop improvement are well taught at the universities in the United States as well as in Latin America.' However, it is in the application of these principles to solving problems that deficiencies occur.

The difficulty of defining, in a means-ends framework, what the objectives of technology policy might be for traditional societies should not be underestimated. The conflict between the farmer's own perception of his needs and an external agent's perception of these needs is highlighted by Green and Hymer[11] in respect of West African cocoa producers. 'The response to proposals by agricultural experts and extension workers has very often been one of indifference, rejection and even open hostility.' The same point is made by Helleiner:[12] 'Many of the innovations pushed on unwilling African smallholders by colonial agriculturists are now regarded as having been uneconomical.'

Innovation, whether it is in developed or developing countries, releases a set of forces which will be transmitted throughout the whole of society. In the context of agricultural innovation, the first-round effects will be felt on the level and mix of outputs; on the level and mix of inputs; and on the level and distribution of incomes. The second-round effects will involve a consideration of the impact of the innovations on the distribution of farm sizes; the development of markets for both outputs and inputs; on the relationships between groups in the rural sector; and on the relationships between rural and non-rural sectors, including government. It is clearly beyond the scope of this paper to discuss all of these dynamic effects. Rather I will restrict myself to a selected few to highlight the fact that innovation does have both seen and unforeseen consequences. This divergence is clearly present in the context of the Green Revolution. The primary objective of the improved wheat, rice and maize varieties was clearly one of increasing total grain output. However, in the process, side-effects, which were clearly not intended, did occur. An outstanding critic of the Green Revolution, Griffin,[13] has argued that 'it is not possible to claim that the new seeds and the accompanying technology have increased agricultural production per head or reduced malnutrition.' At the same time, Griffin has argued that 'the indirect and qualitative effects, however, have sometimes been significant, particularly when one focusses on specific regions or localities. The new technology has led to changes in crop patterns and in the methods of production. It has accelerated the development of a market-oriented capitalist agriculture. It has hastened the demise of subsistence-oriented peasant farming. It has encouraged the growth of wage labour and thereby helped to create or augment a class of agricultural labourer. It has increased the power of land owners, especially the larger ones and this in turn has been associated with a greater polarisation of classes and intensified conflict.'

The fact that the new wheat varieties have found an environmental niche in the irrigated wheat-growing areas of the Third World countries has meant that regional differences have developed, with the irrigated areas being benefited relatively more than the rain-fed areas. Yet, in a country like India, almost 80 per cent of the arable land is rain fed and as one might expect, the poorer groups of Indian farmers are located in these areas. In a controlled water situation, it is relatively easier to develop and deliver a technology which will substantially increase yields per hectare and total output than it is to deliver a technology for rain-fed conditions. Under rain-fed conditions, particularly for subsistence agriculture, survival of the farm household receives greater emphasis as an objective than one of increasing output. Particularly so when this increased output may entail higher risks with crops subject to pronounced water stress on poor soils or with crops which are particularly susceptible to disease and insect attack.

According to Wellhausen,[14] the maize programs have been 'successful' in selected areas of Mexico, Guatemala, Colombia, Ecuador and Peru. The criterion for 'success' in the corn program in Bolivia is that it will enable the cities to be fed and in Peru that the program has led to a great increase in meat and egg production based on corn feeding. However, in all these countries, the high-yielding-variety technology has had little impact on the rural corn eating people who live in the highlands. In Mexico, some 70 per cent of farmers are still at subsistence level and these subsistence farmers and the landless agricultural workers comprise some 40 per cent of the total population. It is arguable that the high-yielding wheat program in Mexico almost certainly would have benefited urban dwellers consuming wheat-based food products more than it benefited the small corn-growing farmers. The other major beneficiaries were the larger commercial wheat farmers in the irrigated areas of the Pacific North-West and Central Bajio areas of Mexico.

Because much of the agricultural technology which is delivered to Third World countries has a specific commodity orientation, it may have consequential effects on the output of other commodities as farmers substitute the improved variety for other crops. For instance, there is evidence, Dalrymple,[15] to suggest that in India land has been shifted out of chickpeas between 1963-1965 and 1970-1971, where a cash grain crop is being substituted - because of improved technology specific to that crop - for the pulses. This substitution clearly has nutritional implications since the pulses are the major source of protein in the Indian diet. The same nutritional implications are drawn by Weil,[16] where an improved technology (the ox-plough, improved varieties and fertiliser) based on ground nuts has led to a decline in basic food crops grown on dry land, in particular, late millet. In order to compensate for this decline, villagers in Gambia have moved to increase production of rice on the tidal swamp areas. So a change in the output mix was associated with a locational change of agricultural activities. However, a move to a new area which may be relatively simple with Gambia's land endowment, may be almost impossible in India with her land endowment. A detailed study by Price[17] on the impact of the new rice technology in Asia suggests that it was only in Taiwan that there was a visible increase in agricultural output at the *aggregate* level, although in particular locations the new technology had substantial effects. The particular factor which allowed this increase in aggregate agricultural output to manifest itself was mainly the early maturity characteristic embodied in the new varieties and the consequential development of multiple cropping.

Changes in the Input Mix

So far, in tracing out some of the dynamics of technical change, I have concentrated mainly on some of the intended effects on output and on some of the unintended consequences as substitutions between products occurred. However, innovation will effect not only the output mix but the input mix as well. It is in the context of changes in the input mix, particularly with respect to labour usage, that innovations have generated a substantial literature in the context of the developing countries. More recently concern about the impact of innovation on labour usage has arisen in the developed countries as well. The recent (1978) telecommunication technicians' strike was to a degree associated with the labour displacement effects of new technology. Without entering into the complexities of that particular dispute, it does highlight the potential that technical change has for labour displacement. However, one should not extrapolate from a single micro-situation to the economy as a whole. The traditional argument of economists has been that while technical change may cause the displacement of particular labour skills in the short run, in the long run it generates a demand for other skills and in a growing economy the displaced labour will find alternative employment opportunities. However, even in a developed society such as our own, if the displaced labour simply adds to the dole queues, then it may indeed be questioned whether the change in technology was immediately beneficial.

It is in the context of relative factor proportions - innovations are described as labour-saving, capital-using, or the reverse - that much of the discussion on the impact of technical change has occurred. In particular, in Third World countries which possess high labour to land ratios, the potential of agricultural innovation to absorb labour within agriculture assumes considerable importance. For example, if land is scarce and labour is relatively plentiful, then biological innovations will tend to increase yields per hectare and will be more effective in leading to increased output per worker. If labour is scarce and land relatively plentiful, such as has characterised Australian agriculture, then mechanical innovations which increase land per worker will be more effective in raising output per worker. In the context of labour use, we have to remember that labour is a non-homogeneous quantity and aggregation tends to ignore the impact of innovation on particular types of labour. In the rural area, the latter may be owner-operator, tenant or sharecropper, family, hired, male or female.

The fact that particular types of technical change may discriminate between different types of workers is clearly illustrated in the context of many irrigation projects. Irrigation projects constitute a favoured vehicle for transmitting new technologies to Third World countries. That irrigation projects will change the input and output mix and result in a commercialisation of agriculture can hardly be unexpected.

An irrigation project immediately produces differences in development between regions. These differences would be of little consequence if overall development took place. The argument would be that increased output from the irrigation project would have linkages with other sectors, both rural and non-rural. These linkages to be effective, should stimulate the demand for rural output from the non-irrigated areas and for labour-intensive commodities and services from the non-rural areas. Unfortunately, the increased income from irrigated agriculture often accrues to local power elites, whose consumption patterns are for capital-intensive imported goods. These same elites often control the information flow from farm to research agency, so that the agricultural innovations that are developed are landlord biased.

At the beginning of many irrigation projects, there is a predisposition towards equity, usually reflected in all settlers having approximately the same farm size. Often the notion of equity is subordinate to administrative ease. Chambers[18] quotes the propensity of expatriate managers of such projects to put high values on 'orderliness', 'predictability' and 'exact measurement'. The local management is concerned with increasing output of the relatively few crops which enter the market, while the farmers themselves may be more concerned with aggregate output, including livestock and produce from home gardens which do not. Even with the best intentioned notions about equity between settlers, subsequent developments have produced inequities as landlordism developed. According to Chambers and Morris,[19] in the MWEA rice scheme in Kenya, landlordism was reduced by making tenants remain on their holdings during the production cycle. Other requirements of the scheme disadvantaged women, since the loss of output from home food gardens deprived them of a source of food for their children as well as a source of extra income. Although the growth of landlordism has been minimised, the management of the MWEA scheme has nevertheless contributed to inequities between farmers with the practice of allocating extra fields to those farmers who have maintained high per acre deliveries. The inequity between farmers is also added to in that the surplus generated by higher deliveries and extra fields has been used to support trading activities.

In a sense, the dynamic of development is under way, and it may be that some inequities will always result as technical change alters not only the technical relationships on farms but the social and economic ones as well. These relationships will be continually altering as the dynamic forces unleashed by innovation work their way through the economy. In the early stages, 1963-66, average cash income from paddy alone in the MWEA scheme was pound Kenyan 116-140, while in the districts from which the settlers had come the average for 1963 was pound Kenyan 52. However, with the advent of improved maize technology, the differentials were markedly reduced. Technological change has to be considered in a dynamic context and the changing relationships have to be continuously monitored if technological change is to achieve the targets set for it. To introduce an agricultural innovation as a 'one-off' action is to set loose forces for change which, unless continuously re-appraised, may result in outcomes completely incompatible with the original set of objectives which led to the innovation in the first place.

The MWEA irrigation scheme, along with the Kenyan small-holder tea project described by Uma Lele[20] and the British-American tobacco scheme in Tanzania described by Scheffler,[21] are all examples of innovations in agriculture where there was a substantial management input either from expatriates or from the relatively scarce indigenous management resources. Unless there is a training component allied with the innovation there is a tendency for intensive settlement schemes to regress. Even the provision of intensive management cannot of itself make for successful innovation if the technical parameters are wrong or the receptivity of the local population is low. The MWEA scheme, despite the evidences of trade-offs between various participants in the scheme and between participants and non-participants, is usually regarded as a successful innovation. The contrast is often made with a similar intensive irrigation scheme, the Perkerra scheme in Kenya. The latter would have to be regarded as less than successful. The river flow is small and unreliable, the eroded catchment area led to flash floods with consequent silting, nut grass invaded the irrigation basins, animal and insect pests destroyed crops. At the same time, the people involved in Perkerra were less used to a cash economy, less hard working, and less willing to accept the discipline laid down under the Trust Land (Irrigation) Act.

My brief was to discuss the intended and unintended consequences of technological change on individuals and on societies. I have elected to discuss the topic at a disaggregated level because it allows the impact on particular individuals, particular regions and particular groups to be seen. To discuss the topic at a highly aggregated level fails to disclose the side-effects of technological change. However, even at a highly aggregated level, innovation does have consequential effects on other large sub-aggregates in the economy. For example, the technology which is being developed in the industrialised societies in large measure reflects the relative availability of resources in such societies and is becoming progressively more capital intensive. When such technology is transferred to developing countries with different relative resource endowments, it leads to a smaller expansion of employment as the technology becomes increasingly more capital intensive. The consequence is that, even in the modern sector of developing countries, the contribution that technical change makes to employment levels may be relatively small. Allied with the growth in population, it then devolves on the agricultural sector to become the residual employer for the expanding population.

According to Frances Stewart,[22] '5 to 15 per cent of the labour force is equipped with the modern technology. The rest suffers from almost complete neglect. The minority equipped with advanced country methods have high productivity and high incomes; the majority, lacking more modern equipment and deprived of most investment resources, suffer from very low productivity. The wide disparities in incomes between the sector using advanced technology transferred from the advanced countries and the rest of the population are largely responsible for the unsatisfactory income distribution in many developing countries, and for the employment problem.' Even the small percentage of R&D which is carried on in the developing countries is often an extension of Western modes, and may be only marginally related to productive sectors of the community. Speaking of Latin America, Herrara[23] says, 'The few basic research centres of quality are generally closely connected with the scientific systems of great powers (both in the type of research they do and, in many cases, in the sources of funding they use). They function as isolated enclaves which do little to encourage local R&D.'

A POLICY FRAMEWORK FOR DISCUSSING INNOVATION

I hope the foregoing discussion has illustrated the proposition that innovation is a dynamic force in the economy and that its actual effects are often at variance with those that were originally intended. The criteria which are usually employed in choosing particular innovations are the following. First, is the innovation scientifically and technically feasible; second, is the innovation economically viable; and third (with a quick nod in the direction of the externalities which innovations may produce), is it safe? These three criteria, I suggest, are inadequate to form an overview of the impact of innovation in society. The 'bad' results from technological change usually arise from a failure of the scientists and technologists, or the marketing men, to address important considerations, which are simply overlooked, or because the impact of the innovation is subtle and cumulative over long periods, so that its side-effects are not immediately obvious. Another reason for the economic 'bads' of technological change is that even when the 'bads' do occur, they are thought to be outside the perceived responsibility of those who are generating the innovations and those who are marketing them. Clearly, however, this calls for some overview of technological change if private responsibility is insufficient to take a broader social view.

For such an overview, one analytical device which has been suggested is the Sabato[24] triangle. The triangle constitutes a simple geometric image which can be used as a vehicle for screening and evaluating scientific and technological options. One vertex of the triangle consists of the government decision-makers who will determine the objectives to be achieved if development is to occur. These objectives will reflect the basic values and the underlying philosophies which govern national objectives in the countries concerned. The second vertex consists of the scientific and technological research resources which are available, both domestically and from overseas. The third vertex consists of the productive sector of the economy, which is the user of the output from the scientists and technologists.

Each of the vertices will be connected with a two-way flow. Government policies with respect to development should influence the directions which R&D takes, while at the same time scientists and technologists should inform government on the possible supply of new scientific and technological knowledge. The interaction will also occur between the productive sector and the scientists and technologists, with the former indicating the demand 'pull' for innovations and the latter showing a science and technology 'push'. There will be a similar two-way flow between government and the productive sector, with the latter transmitting information about the policy environment needed to ensure that innovation will contribute to development while government should be able to influence the sorts of technologies which are actually used by the productive sector. There will need, of course, to be an information flow throughout the whole triangle as well as the necessary infrastructure to enable information to flow. Clearly, if neither of these conditions holds, then the possibilities of using scientific and technological knowlege for development are considerably reduced. Moreover, the intended objectives of research and development activity are less likely to be achieved. At the same time, unforeseen consequences both for individuals and for society are more likely to occur. Such a policy framework stops short of the establishment of technology assessment centres such as characterises the separate Office of Technological Assessment in the US Congress. See Coates[25] for the operation of such an office.

In conclusion, let me say that while science and technology has an important role to play in development, it would be simplistic to think that a scientific and technological 'fix' is all that is required. The economics of development is littered with such simple 'fixes'. There are no simple solutions to the problems of development and the answers lie in the complex matrix of resources - including the scientific and technological ones - politics, economics and general ideologies and philosophies.

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IDEAS WHOSE TIME HAS COME: THE WAVES OF SOCIAL CONSEQUENCE FROM SCIENTIFIC AND TECHNOLOGICAL ADVANCE

BY

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> 'There is one thing stronger than all the armies in the world and that is an idea whose time has come.'
>
> Victor Hugo

1. INTRODUCTION

Unemployment or freedom from drudgery; master or servant of machine logic: these are the two sides of a machine intelligence future. Machine intelligence has more potential to revolutionise the nature of work in industrial society than other major scientific and technological breakthroughs over the last 30 years. However, only a few may benefit because industry is capital rather than labour oriented. Social relationships may be and freedoms moulded according to the logic of machines rather than the logic of humanity.

This paper will evaluate the social significance of advances in machine intelligence as the key factor in understanding contemporary social change produced by science and technology; examine its social impact against the historic background of major shifts in basic techniques of society since the industrial revolution; and assess institutional constraints which are likely to set a particular course for the impact of machine intelligence in the future. The *tool* of machine intelligence will, as with other major changes in basic techniques of a society, *transform the user*; but with an understanding of what is going on, we may be able to have a say in what we become.

2. DEVELOPMENT AND IMPACT OF MACHINE INTELLIGENCE AND MICROPROCESSING [1],[2],[3],[4],[5]

Not very long ago computers did not exist, or were the large-scale playthings of a select group of experts. Now they are an increasingly visible fact of life; even a schoolchild is likely to have one packed in the schoolcase next to his or her sandwiches. The first modern computer, designed by Zuse, was used in Berlin in the early 1940s, and shortly afterwards (1944) the Harvard Mark I was completed in the United States.

These inefficient electro-mechanical devices were rapidly replaced two years later by ENIAC, the first *electronic* computer, which had 18 000 vacuum tubes and filled a 20' x 40' room, and two years after that (1948) by the first stored program digital computer. From 1948, as the enormous market potential for machine intelligence was recognised, two major and related movements occurred in computing technology: movement towards greater computational power, and miniaturisation. Fundamental to these advances were the invention of the transistor in 1947, breakthroughs in semi-conductors and miniaturisation processes during the 1950s, invention of the planar transistor in 1958, the integrated circuit (at Fairchild Semiconductor) in 1959 and large scale integration (LSI), which produced the microprocessor in the early 1970s. The microprocessor is the matchbox-sized heart of a digital computer, and it revolutionised the machine intelligence market by making computers small, powerful and inexpensive. The speed of change in computer technology over 35 years is summarised by Noyce:

> 'Today's microcomputer, at a cost of perhaps $300, has more computing capacity than the first large electronic computer, ENIAC. It is 20 times faster, has a large memory, is thousands of times more reliable, consumes the power of a light bulb rather than that of a locomotive, occupies 1/30 000 the volume and costs 1/10 000 as much. It is available by mail order or at your local hobby shop.'[3]

With the rapid and widespread acceptance of microprocessing technology, the impact in the 1980s is likely to be staggering. Since their introduction only four years ago, microcomputers have rapidly diffused through industry: 100 000 microcomputers were sold between 1975 and 1978, whilst world consumption of integrated circuits (the core of microcomputers) in 1976 generated $3.5 billion - for tiny devices only invented 15 years previously. They are capable of complex decision-making and information-storage tasks, and can substitute for many intellectual functions formerly performed by humans. Kay[6] projects that by the 1980s the personal computer, with sufficient storage space to support high level computer languages and interactive graphic displays, will be generally and cheaply available. The range of uses will be enormous. Even child level software is already being designed: Kay has developed SMALLTALK, a computer language for children. Furthermore, 'smart' machines will increasingly be incorporated into production systems: Noyce[3] projects that by 1986 the number of electronic functions incorporated into a wide variety of products each year will be one hundred times what it is today.

However, the impact of machine intelligence so far has been set in the particular economic context of the post-war years and has been most keenly felt in the area of employment. The labour market of the 1950s and 1960s was characterised by labour scarcity, persistent pressure on labour costs, labour disputes, international trade competition from efficient producers with low labour costs, and government tax policies which encouraged capital investment and labour replacement. Economic conditions were ideal for machine intelligence to fulfill the role of replacing labour by capital. Forces creating labour displacement in the 1960s through automation established a theme of technological change for industry of the 1970s, when world wide recession eroded demand and left much of Australian industry operating below installed capacity. With a drop overall by 10% in the use of installed capacity between 1973 and 1977 and tax incentives which favoured capital investment, the bulk of investment in Australian industry in the 1970s has been directed towards labour replacement rather than to incremental change in capacity.[7] Faced with overproduction, industry had little choice but to replace the increasingly costly labour component of production costs to maintain profitability. The role of machine intelligence in the replacement of labour by capital is difficult to extract from official statistics on unemployment. There are few figures that directly relate unemployment to cause and separate effects of machine intelligence from automation. The impact is also likely to be accelerating, particularly since 1975, with the more pervasive effect of microprocessors.

However, data reported by Freeman for the United Kingdom, and by Robson, Emery and Windschuttle for Australia, are highly suggestive.[8],[9],[10],[11] Their evidence indicates that microprocessing technology in conjunction with automation and work rationalisation is already making heavy inroads into employment. The pattern of effect is diffuse, but particularly impinges on semi-skilled employees. Office workers have been particularly affected by word-processors: Windschuttle reports an estimate that 20 000 typist jobs have been eliminated by word-processors in Sydney alone.[11] An integrated technology of mini- and large-scale computers is replacing production personnel and middle management functions, particularly those concerned with information processing, as well as reducing the skill level in many jobs. The most direct evidence of the impact of machine intelligence in Australia is to be found in a series of surveys conducted by the Department of Labour and National Service/Industrial Relations on the impact of the EDP industry in Australia.[12],[13],[14] These surveys demonstrated that growth in employment generated by the EDP industry in a sample of firms was outdistanced by employment displaced specifically as a result of EDP use. In the five years prior to 1973 (before employment levels dropped dramatically), the Australian EDP industry grew by 12.2% per year in employment - particularly for specialists in software development. In 1972-73, 3080 jobs were created in the sample of firms surveyed but 3266 jobs were replaced, representing 2.7 times the number of jobs replaced in 1968. Industrial firms were also finding it harder to reabsorb personnel displaced by EDP: whereas in 1968, 21% of displaced workers were retrenched, by 1973, 32% were thrown onto a labour market in which jobs were increasingly hard to find and average length of time out of work was starting to exceed six months.[15] Forty-eight per cent of people displaced by EDP were office clerical workers, whilst 74% of people displaced were women.

This was the direction that industrial technical change was taking in 1973. Unfortunately, there are no survey statistics that show what has happened since microcomputers penetrated the market. However, it is likely that the cheaper new-breed machines have accelerated the trend towards labour replacement.

Thus, while microprocessing development in the 1980s will offer generally available computational and information-processing capabilities of extraordinary power, there will also be increasingly pervasive structural unemployment. Both of these trends will continue unless the linkage between computerised intelligence and industrial use is mediated, alternative sources of employment are generated, or, at least, the employment consequences of computer-based industrial automation are redistributed. To identify the role of Government and of scientific research in directing future technical change towards an equitable and people-centred society, we must draw on two lessons - one sociological and the other historical. In addition, lessons must be located from history with respect to the unique economic and social conditions of the 1970s. Computerised intelligence represents an 'idea whose time has come', but as with all ideas which become social movements, to understand its genesis and consequence we must locate the social milieu which has given birth to the idea, and facilitated its diffusion.

3. INTERDEPENDENCE OF TECHNOLOGY AND SOCIETY - LONG CYCLES OF TECHNOLOGICAL IMPACT

The fundamental interconnection between productive techniques and the whole fabric which holds a society together is often forgotten when we focus too closely on the impact of particular changes in the techniques of a society. All societies - both traditional and modern - are social systems, with an interdependence between the economic and social structures that define relationships and interactions between its members: culture, which expresses and sustains the symbolic meaning of action within society; 'world views' and 'theories', which organise attention around what is meaningful and legitimate in social beliefs; and technologies and techniques which extend human capabilities and provide the basis for the productive activity that sustains the society. A change in one dimension will produce changes in the others. Change in technique produced in a particular social and economic context may have a profound and pervasive impact on social institutions, culture, world views, and economic opportunity throughout the entire society.

Simple traditional societies are based on simple and relatively stable technologies, knowledge of which is essentially accessible to the whole community. An apparently small change in technique, introduced from outside the existing social/technical equilibrium, can disturb this equilibrium profoundly. Sharp's example of the effects on social structure caused by missionaries introducing steel axes to Australian stone-age Aborigines demonstrates this disturbance.[16]

Industrialised society is, however, based on complex interwoven use patterns of a vast range of specialist-controlled 'black box' technologies which are largely controlled by vested industrial interests. Contemporary technologies and productive techniques are therefore generally beyond the immediate influence of the layman. Consequently, though produced in a congenial economic and social milieu, modern-day technical change can well be like an invasion of a society from within - an invasion that follows a route made navigable by existing economic relationships. However, with the complexity of a modern technical base and the familiarity of the society's people with change, the impact of technical change is likely to appear as fitting into a seamless web of continuing growth and 'progress'. It is only when we step back and look beyond the impact of specific technical changes that we can identify radical perturbations in our social system caused by innovations which 'bunch' together.

Recent analyses suggest that there have been four identifiable basic transformations since the start of the industrial revolution. Two authors, Emery in Australia and Freeman in England, suggest that microprocessing technology represents a fifth transformation, the effects of which are presently upon us.[10] The argument which identifies cyclical consequences of bunchings of basic innovations is based on refurbished versions of long-wave economic theory originally proposed by Kondratieff in the 1920s.[17],[18],[19],[20],[21],[22] Although differences between countries in resources, population growth levels, stages of development, technological capabilities and external controls affect their particular growth and decline period, a generalised world trend can be identified. There are several important characteristics of long cycle theory - particularly where Kondratieff's more limited account is extended to the enormous restructuring it implies in the technical and social base of industrial society.

(1) Kondratiev theory (in a somewhat remodelled version) identifies take-offs into new cycles of economic activity which occurred (depending on the author) between 1781-1790, then 1848-1851, 1894-1896 and 1934-1940. Each new cycle took off as important bunchings of inventions in production and energy use made during previous cycles were called into large-scale service by a conducive economic climate. With each new cycle came large-scale restructuring of production and of social relations; growth within the cycle was then borne on the wave of opportunity this created. There has thus been a series of technological 'ages' which set the context for the application of other inventions during that period, and radically transformed society in the meantime. The major bunchings of technological advance which approximately align with economic cycles are (a) the 'age of textiles', or the 'age of machinery for the textile industry' (including steam technology), and the 'age of iron'; (b) the 'railway age' and the 'age of steel'; (c) the 'age of electricity' and its major derivative, 'the chemical age'; and (d) the 'age of the internal combustion engine' and, with the major impact associated technical advances had on mass consumerism, the 'electronics age' and the 'age of plastics'. Contemporary theorists suggest that with a downswing in the age of the internal combustion engine, the world economy passed a critical point around 1972 when food and oil prices escalated, growth in mass consumption declined, but where rebuilding of industrial production along new technological lines - utilising computer intelligence - was gaining momentum. The most essential consequence of this long cycle analysis is that it suggests that a downturn in long economic cycles results from saturation of previously released economic opportunities, so that recovery is based on new core technologies rather than on the use of capital to further exploit incremental improvements in existing technologies. However, whereas take-off into the four previous cycles has occurred in a context of possible economic growth and plentiful physical resources, the impact of microprocessors is set in a context of contraction in physical resources and limitations to economic growth.

(2) The idea of 'bunchings' of technological advance suggests waves of social consequence which diffuse through the entire society. Each new 'age' has created enormous investment and employment opportunities in the new industries, as well as new possibilities for the relocation of factories, offices and distribution facilities. As a result, the nature of work organisation and society as a whole undergoes radical transformation - a social transformation which underlay the economic changes which characterised subsequent cycles.

For example:

(a) Textile technology involved factory organisation and required the separation of work from home life. With subsequent industrial concentration came social division between owners of capital and owners of land, between owners of capital and labour, and between town and country. Thus, the basis was set for organised labour as a political force. With industrial concentration came the birth of the modern industrial city as the dominant mode (in the 20th century) of human living.

(b) Railways technology, closely linked with the emergence of the steel industry, radically altered the economic and social exchange horizons of people. City was joined to country and to the commerce that was conducted in the towns. As Rostow observes of the United States, 'the railroads were surely connected in one way or another with immigration, with population increase, internal population movement, and with almost everything else that mattered in the American economy'.

(c) Electricity and related technologies allowed energy distribution and gave rise to the development of high energy-consuming production systems, such as in the chemical industry, and laid the basis for very large-scale business organisation systems. On the other hand, electricity technology provided a distributable energy source which, in the individual's own home, powered the subsequent consumer products revolution. Furthermore, the 'electricity' age heralded in the early stages of the close alignment between scientific and technical innovation and competitive economic advantage. The period from the 1890s to the late 1930s saw the scientifically-trained engineer emerge as a numerically significant professional class, responsible for the continuing development of innovation.

(d) The age of the internal combustion engine took off on the basis of the society created by the three previous cycles. Assembly line social organisation was introduced to handle complex technical arrangements of production, and yielded an organisational form which fundamentally underlay the development of consumer products industries. Automobiles radically transformed transportation and communcations systems: they led to the creation of suburbs which, as Schon observes,[22] in turn changed prevailing theories of the function of cities, which

> were seen no longer as places to live *and* work; broad-ranging patterns of decentralised services and products were set in motion; estates in the suburbs transformed the nature of neighbourhoods; and use of public transportation radically declined (by 64% in the United States between World War II and the 1960s).[24] The relative isolation of the suburban house called into being a complex of services that led to the suburban culture. Isolation and anonymity, by-products of a suburban form, private transport, and geographic mobility evoked a 'status anxiety' and led to 'conspicuous consumption'.[25]. Such a social dynamic was a necessary basis for a mass consumer society. The internal combustion engine thus laid a seed-bed of social acceptance for consumer-oriented synthetic process and electronics industries which were planted into this long cycle of development.

The use of computerised intelligence comes within the social forms produced from previous long cycles of development. However, with the downswing of a previous mass-consumption cycle, particular problems will be created where the existing character of the industrial production-mass consumerism nexus is broken. I will come back to this shortly.

(3) Long economic cycles attributable to bunched technological innovation appear to bear a cyclical relationship to employment. Freeman[8][21] argues that long cycles are 'job-generating' in their early stages, but 'job-displacing' as they mature and previously opened when job opportunities become saturated. Furthermore, as cycles mature, the structure of employment in core industries of the new technological complex become, more centralised as standardisation, economies of scale and centralised ownership increasingly hold sway.

(4) Technologies that lead to cost reduction have traditionally led each new long cycle. For example, of the four sources of power available for the early automobile (steam, electricity, Otto and Diesel cycle engines), the Otto engine was chosen because it was the *cheapest* and most reliable.[26]

(5) Finally, long cycles appear to have been boosted by new sources of energy supply which allow faster growth and greater technical simplicity than the previous source and by new power technologies that can effectively utilise the energy source. Emery[10] observes that the textile age took off on the over-shot water wheel; the second cycle was the age of coal; the third was the age of electricity; and the fourth, oil, thence natural gas. Mandel[27] argues that the *basic* technological development of each new wave is in power technology - from handicraft-made or manufacture-made steam engines, to machine-made steam engines, to electric and combustion engines, to the generalised control of machines by electronic apparatuses. This has allowed the *use* of developing energy sources and has so powered the growth of a new wave of economic expansion.

Consequently, cheaper and more versatile new energy sources gain momentum as the more dominant energy sources as the cycle matures. From the end of the first cycle, when wood was the source of 90% of energy used in world industrialisation, coal use grew from 10% (1890) to 94% in the early 20th century before declining through the third and fourth cycles to 32% (1974) of the total. The use of oil has risen from 4% (when coal made up 94%) to 45% (1974) of total energy during the third and fourth cycles. Meanwhile, through the fourth cycle, usage of natural gas has risen from 4% (1929) to 21% of total energy production in 1974.[28][29] Which energy source can rise to dominance in the future is, however, uncertain.

4. INHERITANCES FROM THE PAST

There are significant implications which follow when we align computerised intelligence against these observations. However, as noted earlier, its impact is set in the social context we have inherited from previous cycles of growth and social change. In particular, social change within previous cycles has led to increased concentration of business enterprise and capital. As well, increased incorporation of science into leading firms has dramatically transformed their nature and marketing strategies.

The world economy is now largely influenced by large multi-national corporations. Multi-nationals controlled 20% of industrial output of the capitalist world and 30% of world trade in 1970-71, and had $30-35 billion in liquid assets, three times as much as the gold and currency reserves of the United States.[30] By the end of this century, 200 to 300 multi-nationals may well control 75% of the private assets of the capitalist world.[31] In the context of such 'bigness' and with consumer markets close to saturation, leading sector industries increasingly have to rely on scientific and technical advance to create new markets. During the first few decades of this century 'classical' business firms were organised around a product, took a particular technology and the demand for their particular product as given, and were organised in a pyramidal structure which linked established functional units in a chain of responsibility.[23] Under the influence of development and use of wartime technology and saturation of traditional markets competition became more technologically based in producing new markets. As scientific and technological capabilities were built into firms, organisational changes occurred in order to more effectively use scientific research. Central research laboratories were established, and new product lines generated from research required the development of autonomous subsidiary companies. Firms defined their products more generally - shoe businesses became 'footwear' - implying a range of different technologies; further movement redefined whole marketing strategies in terms of what Schon calls, 'business systems'. This has enormous implications for the pervasiveness of single business operations, and technological operations required to service them. As well, science-based industries, advancing in capability to use research, invaded traditional industries; the synthetic fibres industry, for example, non-existent before World War II, grew at a rate of 18.4% per annum during the 1950s, and 21.1% during the 1960s.[5] Consequently, in the context of market redefinition, clusters of industry became locked together, 'textiles' becoming a 'textile-chemical-paper' complex, for example.

Furthermore, with the continuing explosion of scientific enterprise and its sub-specialisation, the very large leading firms were more able to recognise and transform scientific advances into industrial technical advances because they employed 'translators' (in research laboratories) who could match new markets with new specialised scientific production capabilities. These firms also had the organisational base to spin-off satellite firms around new scientific developments that the corporation controlled. This pattern of linkage has yielded a skewed impact of scientific knowledge over the last 30 years, accelerating the advantage of corporations which are science-based, large scale, and which employ a pervasive marketing strategy. As Freeman demonstrates for the United Kingdom,[5] innovation in industry has, as a consequence, been largely produced in 'giant' firms, of over 10 000, who accounted for 54% of innovations between 1945 and 1970. Meanwhile small firms, of less than 200 employees, accounted for only 10% of industrial innovation, whilst their share of both output and employment declined.

Consequently, maturation of the last long cycle has occurred with rapidly accelerating corporate bigness and pervasiveness. Scientific research and technological change have specifically fed this growth and transformed the nature of business organisation to cope with expansion. The boom of expansion into technologically created markets (rather than population and migration created new markets) rapidly reached saturation point at the end of the 1960s. The problems large leading sector firms face have since increasingly involved rationalisation of existing capacity and reduction of production costs rather than the expansion of capacity.[8] The limits of growth this time - as opposed to downturns at the end of other Kondratiev cycles - are related to an increasing consciousness of both the ecological destructiveness of fourth cycle growth and the absolute limits to resources available for exploitation. The consciousness of such limits is reflected in the sudden increases in food, raw materials and petroleum energy prices observed by Rostow[18] to have occurred in 1972. If science and technology are to provide solutions for a new economic order, it is only likely via the large pervasive enterprises that dominate the present leading sectors, and these are organisationally and economically dependent on the past order. The institutional inertia towards radical structural and social change is potentially enormous.

5. COMPUTERISED INTELLIGENCE - A CYCLE OF THE FUTURE

Born in the womb of a consumer-automotive age came computerised intelligence. The social conditions inherited from the fourth cycle will, however, determine the way in which it is applied, whose interests its application will serve, and the social consequences likely to flow from it. Computerised intelligence in general, and microprocessing in particular, presents change of the order of magnitude which has characterised the 'bunched' technological changes of previous cycles. Its effect though, is mediated by different social forces from those which set the milieu within previous cycles.

Microprocessing innovations represent the kind of 'bunchings' of technological advance which have characterised previous cycles. They have involved major technical changes in the use of materials, in processing, and in products available to the general public. The capability of making all our machines and their interdependent parts 'smart' offers a pattern of diffused technological change that can potentially spread through the entire economic infrastructure. The social transformation is extensive, with diagnostic and information operations being largely eliminated and information collection and use being increasingly centralised. In particular, as noted earlier, computerised intelligence is radically altering the levels of employment required to sustain the present industrial system. Microprocessing technology also offers significant cost reductions across the entire economic system, as have the bunched technologies of previous cycles. The cost of just about every machine system is reduced, and in the majority of cases, thrown in as a gift, performances that were previously desirable, but too expensive to offer, are achieved.[10] Even in contemporary electronic equipment rarely does the integrated circuit cost more than 10% of the total product cost, and with each doubling of industrial experience, the integrated circuit cost decreases by 28%.

The 'bunching', diffuseness and cost advantages of microprocessor technology suggest its role as the core of a fifth long cycle. However, the present situation is different from previous periods of cycle upswing in important ways. While former 'bunched' technologies tended to be associated with an evolution in cheaper, more flexible, and more available fuel supplies, the immediate future does not offer such a potential. Nuclear energy has just too much impact on both the physical environment and the potential for social instability to be treated as more than a stop-gap measure and the use of energy from renewable resources is technically unfeasible on a large scale at this stage. The energy future is more likely to be one of diminishing rather than of accelerating growth and cost reduction if the present mode of highly centralised big energy technologies and production continues. Microprocessing reduces the energy required for electronics products and can optimise fuel consumption in machines and can be used to optimise the collection of energy from renewable resources. But this is a patching up of the energy hunger inherited from the past - it does not reflect a new wave. What may be called for instead is a major restructuring of energy usage towards more decentralised production since centralised energy production appears to be reaching finite limits, not only of resources or tolerable pollutants, but also of an implied urban population. Centralised energy, production, and cities go together, and urban populations are now becoming too large for viable human existence. 'Smart' devices may well play a role in increasing the efficiency of decentralised energy production as well as in integrating it with centralised energy systems. However, such decentralisation would be reversing the trend of industrialisation over the last 200 years.

Second, each previous cycle appears to have generated employment during the economic upswing, followed by employment reduction in later stages. In the case of computerised intelligence, and thus microprocesses, jobs have been created in the industry itself. The successfulness of the innovation, though, has immediately led to job displacement - both within and outside the electronics industry - before the cycle has really started. This is reflected in Australian data presented earlier.

Although there may well be a continuing steady demand for computer programmers, operators, and so on, there is little prospect for major new sources of employment generation, particularly in Australia where we have no computer manufacturing industry. The result will be either unprecedented levels of unemployment or a major social reconstruction of work hours, job sharing, leisure and so on. With the downturn out of the fourth cycle in a consumer-based economy and with dominance of economic development by large multi-purpose organisations whose *existing* production capacity is underutilised, the trend towards labour rationalisation and replacement is likely to continue - with the aid of microprocessors.

In the past, employment prospects have moved progressively from primary to secondary to tertiary industry. However, prospects in the service sector are now also bleak, with one of the main activities in the service sector, the handling of large quantities of simple information, being increasingly replaced by microprocessor technology. Law, welfare, retailing, fast-food services, telecommunications are, as Windschuttle suggests,[11] open to threat, and are only *examples* of inroads already being made by microprocessors into the service sector.

Consequently, an economic recovery is very likely to be associated with decreased rather than increased employment unless a whole new economic order is introduced. Such a new order would entail favouring labour use rather than capital accumulation, reversing centralisation and 'bigness' in both organisations and urban populations, and guiding the application of new technological inventions by a criterion of social benefit other than cost effectiveness.

Such radical change seems unlikely in the short term. We are, it seems, entering the 'stable state' that Schon foresaw in 1970,[23] but with an institutional framework that is the legacy of four previous Kontratiev technological cycles of *growth*. In this context we must return to the role of science and technology in constructing a viable 'stable state' society of the future.

6. AND WHAT OF THE FUTURE?

The idea of long technologically induced waves of economic and social restructuring has very important implications for future scientific/technological and social/economic policy. The implication is so important that it is worth conjecturing, albeit briefly, about the alternatives we face and possible action we might take.

We are faced with two alternative futures. One will, I believe, plunge society into a quite major disruption, though in the interests of economic recovery, while the other could allow a managed entrance to a new Kondratiev cycle. The first path is uncontrolled as it is dominated by a techno-economic imperative proffered through microelectronics development and diffusion. The second path can only be achieved through management of social and industrial change and also scientific enterprise for society.

The future offered by microprocessing technology is, on the surface, Utopian. It will almost certainly introduce the age of the personal computer, or portable mechanical mind, with all of its multifaceted uses for the curious - in planning, in construction, in selling, in home life-style, leisure and organisation. It will enable the most pervasive and extraordinary mechanical means of communication and eliminate the necessity for large areas of work previously required to sustain a productive economy. What now matters is how we use our 'portable mechanical mind' within a social, economic and physical milieu of limits rather than infinite capacity for expansion.

Recovery in each former cycle appears to have been associated with radical shifts in the technological base of society caused by 'bunched innovations' of pervasive consequence which were born in previous cycles. A technological base is also a social base, so society has shifted with technology. Computerised intelligence and microprocessing were born within the scientific, technical, economic, and social milieu of a fourth Kondratiev technological cycle. With finite resource limits, though, it does not offer the expansion of industrial occupations and labour as with previous cycles. Furthermore, since scientific and technological advance is closely aligned with major corporate interests, microprocessing technology is most likely to serve the interests of those with most capital to invest. With a downturn in a consumer-based economy, this is likely to lead to increased substitution of labour by capital. The social costs caused by an unbridled microprocessing revolution are potentially incompatible with the economic benefits.

There seem to be two ways out. One is to adjust socially - for society to progressively change so increasingly scarce employment is redistributed, involving changed work-hours, shared jobs and so on. In a 'steady state', with fragile management-union relations and the pervasive self-interest of established occupational and capital-controlling groups, this is unlikely to work easily. We can see this in present Federal Government resistance to the NSW

Government's plan to introduce a 35-hour week in the NSW Electricity Commission. Capital interests which harness the new wave technology will continue to dominate. More importantly, merely getting a society accustomed to the unattainability of full employment does not represent the development of a social transformation that, as at other times of cycle shift, has *sustained* growth in a new direction. This time we need to pay attention to the tax on social and physical resources caused by growth and centralisation; we need to conserve increasingly scarce environmental and energy resources. Such social and technical imperatives would appear basic to a 'steady state'.

The second alternative is a major (and at this stage, unexpected) 'bunching' or constellation of technological innovations - with the pervasive impact of previous long cycle stimuli, which integrates with the wave of change unleashed by computerised intelligence, but still meets the 'steady state' criteria of energy/resource conservation and meaningful involvement of people in productive and social life.

Given the immediacy of the alternative futures suggested by this analysis there is every reason to work on both fronts. However, whereas scientific and technological knowledge have proven time and again their joint power to provide resilience in industrial growth, the social milieu, this time, cannot be coerced along as easily as when Henry Ford gave his employees the exorbitantly high wage of $5, heralding in the age of consumerism. At least, it cannot be coerced into a social 'steady state' by the present direction of technological/economic advance. The implication is that the social and resource criteria need to be integrated with technical criteria in problem definition and research design criteria. This also suggests that Government needs to promote the use of scientific and technological advance according to these same 'steady state' criteria. This suggests a careful examination of priorities in the organisation of scientific endeavour. For example, in keeping with these objectives, science policy should not be decided without cognizance of its social connectedness and priorities of funding *technical* questions and possibilities should be decided in terms of *social* priorities. As a consequence, the structure of policy organisations such as the Australian Science and Technology Council (ASTEC) is inadequate unless informed by social science expertise and 'steady state' awareness; science policy must also be integrated with social, economic and fiscal policy. Research practice and training need to develop scientists with a social awareness of technical design alternatives. This suggests bringing scientists and research trainees closer to the social issues (and analyses of them) that both underscore, and are a consequence of, their technical research.[32] This does not in any sense imply supplanting scientific brilliance or creativity with pragmatic utility but, rather, capitalising on this creativity to draw technical and social parameters of inquiry together. *Radical* innovation is called for, rather than incremental improvement to the existing (pragmatic) techno-economic system; so highly creative scientists and technologists are needed.

Wider government policies are also implicated, particularly those which affect the nexus between scientific and technological knowledge and industrial investment. Labour-generating and 'steady state' conserving, industrial innovations can be encouraged by economic and fiscal policies which do not promote capital investment per se but rather *particular* capital investments of the most appropriate social 'fit'. Small innovating industries, decentralised new production of goods and services, community-based life, work and consumption *can* be encouraged rather than discouraged by government action.

Wiener, the father of cybernetics, poses the possible social consequences and risks of a cybernetic future by using the medieval legend of the 'golem'.[33] The legend, in its later Jewish form, describes the figure of a man constructed from clay or mud which comes to life when the Polish Jews pronounce the name of God, 'Shemhamphoras', over him. The 'golem' cannot speak, but understands well and acts as a servant, but he must never leave the house. On his forehead is written *'emeth'*, or truth, and every day he gains weight until he becomes *larger* and stronger than all the others in the house. To control him they must erase the first letter on his forehead, leaving 'meth', or 'he is dead', so that he collapses and turns into clay. One man did not pay attention to this precaution and let his golem grow so tall that he could no longer reach his forehead. Terrified, he ordered the servant to take off his boots, and when the golem bent down, successfully erased the first letter, but the whole heap of clay fell on the Jew and crushed him.

Microprocessing, as the leading technological arm of future industrial man, has assumed the significance of 'an idea whose time has come'. But if it is to be an integral part of a viable social future, and if associated scientific and technological advance are to be harnessed for the good of mankind, we *must* build social (not just technical) parameters into the organisation and use of scientific enterprise and technological advance. If we do not, the 'golem' we produce may one day crush society rather than act as its servant. Rocklin, in discussing this legend concludes, 'As we cannot long survive as human beings in a world structured to fit the logic of our machines, we must constrain our machines and make them operate according to the logic of humanity'.

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WORKSHOP DISCUSSION

ECONOMIC AND SOCIAL CONSEQUENCES OF SCIENCE AND TECHNOLOGY

REPORTER

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1. INTRODUCTION

The economic and social consequences of introducing new technology are not easily predicted. Much depends on the nature of the technology, the existing economic and social structure and the reactions of individuals and Governments. The uncertainties seem particularly great today, when the rate of unemployment is relatively high in most advanced industrial societies and Third World countries are questioning the benefits they derive from technology introduced from the developed countries.

Given these circustances, there was scope for lively debate on this s[illegible], both in the plenary sessions and in the sydicate discussions, and so it proved. A good deal of emphasis was placed on the unintended consequences, mainly felt to be adverse consequences, for the developing nations and for Australia. Yet some participants were able to inject a note of optimism, claiming that science and technology results in long-run benefits outweighing the temporary costs of social disruption. It was not merely that technological advances contribute to increased economic growth as measured by the rise in gross national product, but that they also enhance the quality of life, when that concept is more broadly defined. This latter proposition, however, did not meet with universal acceptance by speakers at some of the plenary sessions.

Two major themes were present in the discussions. The first related to the likely economic and social impact on Australia of the new wave of microprocessing technology. Was it inevitable that this new technology would contribute to social disruption and to higher unemployment? The second major theme concerned the effects on individuals and on the economic and social organisation in developing countries arising from technology transferred from more advanced countries. What can Australia do to ensure that there are net social benefits to the people of the developing nations from the scientific and technological assistance it is able to provide?

2. MICROPROCESSING TECHNOLOGY

The sydicate examined the arguments put in Professor Hill's paper that long (or Kondratiev) economic and social cycles occur periodically in advanced countries as a result of a bunching of major new technological innovations. Following this line of approach, the industrialised countries appear to have passed through the fourth Kondratiev cycle by the early 1970s, when the impetus provided by the development of the internal combustion engine, plastics and electronics was already losing its force. The question arises whether microprocessing technology will give rise to a fifth Kondratiev cycle and the marked social changes that it would imply. The effects of this new technology on employment may be reinforced by the impact of inflation on real wage costs, which could also lead to the introduction of more labour-saving methods of production.

However, the economists, in particular, were rather sceptical about the existence of Kondratiev technological cycles of the type postulated in Professor Hill's paper. In view of the greatly increased expenditure on research and development today compared with the last century and the enormous rise in the number of trained scientists and engineers, it did not seem very plausible that the bunching of innovations should occur at approximately the same intervals as it had previously. Moreover, it was felt that there was a danger of attributing decreases in manufacturing employment and rises in unemployment since 1973 to the downswing of a Kondratiev cycle, when the same phenomena could be more easily explained by the slowdown in economic growth in nearly all advanced countries, partly brought about by the rapid rise in the price of oil. A further factor behind recent increases in measured unemployment in Australia may be decreased occupational and geographical mobility as a result of increased affluence and the greater incidence of two-income households.

It was conceded that historical studies might reveal that marked changes in economic and social structure have resulted from the widespread adoption and diffusion of major innovations. However, it was quite a different matter to determine in advance whether a new innovation, not yet widely adopted, would bring about fundamental changes in the economy and the social system, and if so what the nature of those changes would be.

This discussion led naturally to a more detailed evaluation of the likely effects of a specific new technology - the microprocessor. There was no dispute about the fact that this technology would create jobs as well as displacing workers. However, there were sharp differences of view about the relative numbers of jobs that would be created and lost. Some argued that, in the past, significant technological change had always brought about the displacement of workers, yet there had not been a marked increase in unemployment. Microprocessing technology was not likely to lead to a different outcome. On the other hand, others maintained that microprocessing technology was distinctively different from earlier technologies which had dramatically changed the economic and social structure (such as the advent of the mass-produced motor-car). In particular, the microprocessor would be widely adopted within a few years in the 'information sector'. There is considerable scope there for labour displacement once the new technology is introduced, and it has to be borne in mind that this sector is not only a major employer of labour in Australia but it has been growing very rapidly in recent years.

A second important difference was that the microprocessor could be manufactured, installed and used without having to call upon a wide range of ancillary manufacturing, construction and service activities. It occupied little space and breakdowns and repairs were fairly minimal. This clearly distinguished it from major mechanical innovations of earlier periods. Thirdly, the microprocessor was very inexpensive for the capacity it could provide and might be expected to diffuse rapidly among firms, thus giving rise to the strong possibility that economic recovery would lead to increased rather than decreased unemployment.

Not all of these propositions were accepted. It was held by one or two participants that the microprocessor would contribute to lowered prices for 'information' and other services, thus leading to increased demand and production. It was likely that this would offset any tendency towards lower employment. Nevertheless, there was a feeling that the widespread introduction of the microprocessor would probably mean some restructuring of the present social order. There would need to be greater emphasis on retraining of displaced workers and on labour-using as opposed to capital-using activities.

There was no shortage of suggestions for useful labour-using activities which might compensate for any loss of employment in the market sector. These included welfare services for the increasing proportion of aged persons in the community and more emphasis on do-it-yourself activities in food production, dwelling construction, etc.

Conclusion: There is a need to study and monitor the economic and social effects of new technology. Society can only influence the impact of science and technology if it is aware in detail of the consequences that flow from its introduction.

3. TECHNOLOGY TRANSFER TO DEVELOPING COUNTRIES

To get to grips with the broad range of issues involved, the participants distinguished between two very different groups of developing countries. On the one hand, there are the poorer countries, many with large populations (eg China, India, Indonesia), in which agriculture is by far the largest source of income and employment. On the other hand, there are the newly industrialising countries with higher per capita incomes, many of which have succeeded in exporting a growing volume of labour-intensive manufactures in recent years. These countries include several in our region, notably South Korea, Taiwan, Singapore, Hong Kong and Malaysia, as well as Brazil and Mexico.

The former group of countries require inproved agricultural techniques appropriate to their particular economic and social environment. A principal objective is to boost food production by at least 2-3 per cent per annum to keep pace with the growth of population. The latter countries are seeking appropriate industrial technology, through direct foreign investment, licensing agreements, or turnkey arrangements. At the same time, these countries also need improved agricultural techniques so that productivity per worker in agriculture can be raised sufficiently to meet the needs of the growing urban workforce.

There was a good deal of discussion in the plenary sessions as well as in the syndicate about the unintended social consequences of agricultural innovations introduced into the poorer developing countries. The introduction of new farming techniques is often accompanied by changes in existing land tenure arrangements. Such changes may lead to decreased rural employment, greater inequality in income distribution between landlords and tenant farmers and a permanent contraction in subsistence peasant farming, as indicated in Professor Jarrett's paper. Some degree of initial social disruption was felt by many to be a necessary cost if living standards were ultimately to be improved. However, there were some steps that could be taken by the Government of a developing country to minimise this disruption. One such step might be the provision of improved rural credit arrangements for peasant farmers.

The view was expressed by more than one participant that the problems associated with introducing new agricultural technology into the developing countries should not be exaggerated. In fact, Australia has played, and could continue to play, an important role in the provision of technical assistance for agricultural improvement to many developing countries, particularly to those with climatic conditions similar to our own.

The question was raised whether Australia has the right or responsibility to control the transfer of technology to a developing country if, in its opinion, the technology might have unfavourable social or economic effects. For example, what is to be the attitude if a particular technology is requested by the Government of a developing country but its introduction would probably favour the 'elite' rather than the poorer members of the society? It was generally felt that this was a matter which the developing country must decide for itself, and Australia should not, on such grounds, refuse to supply technological aid requested by the Government of that country.

A rather more difficult problem is related to the 'images' created, and aspirations developed, within the developing countries by the presence of advanced technology and sophisticated consumer products introduced from the high-income developed countries. Some felt that embassy staff and technical advisers from advanced countries should avoid the use of expensive cars, air-conditioning, and grandiose buildings while serving in a poor country. Yet the majority view was that even if this were done, the developing countries would still be subject to the 'demonstration effect' of advanced consumer products since, in the modern world of rapid communication, there was no way they could be isolated from Western cultures.

Participants pointed out that some of the industrial technology transferred from advanced countries to the newly industrialising developing countries might also be inappropriate to the local endowments of labour, skills and natural resources. Moreover, one of the discussants reported a study of the foundry industry in Thailand which showed that several years after the initial investment in new industrial technology there had been no improvement or modification to suit local requirements.

Several reasons were advanced for the transfer of inappropriate industrial technology and failure to adapt it subsequently. The inability of the local workforce to absorb new technology was regarded as an important factor. Language barriers, inadequate skills, and poor standards of literacy all appeared to contribute to this lack of absorbtive capacity. Basic education and improvements in technical training were thought to be crucial if the developing country was to have the ability to make appropriate choices of foreign technology and to gain the benefits from its introduction.

There was a brief discussion of the role of multi-national corporations in transferring industrial technology to developing countries. Despite criticisms often heard about multi-national corporations, it was concluded that they made a positive contribution to the economic and social development of many developing countries through the technology which they introduced. It was true that some of this technology was highly capital intensive (eg petroleum refining) and made little direct contribution to employment. However, it was often possible to ensure that ancillary activities, such as transport, distribution and building and construction, were more intensive in their use of unskilled labour than would be the case in an advanced country. To that extent, the activities of the multi-national corporation could assist in the employment of the large urban population as well as aiding economic growth. Again, there was evidence that multi-national corporations had assisted in the improvement of quality control by local manufacturers in developing countries through the standards set for the components they purchased.

The benefits and disadvantages of technology transferred from the advanced countries are well illustrated by the growth of the international tourist industry in a number of developing countries. It was argued that the benefits of developing hotel and resort accommodation for wealthy tourists from abroad were reflected in the improved employment opportunities and additional foreign exchange earnings of the developing country. Yet, the disadvantages could be seen in a certain degradation of the local culture, in rising urban costs and possibly in an increase in illegal pursuits such as drugs and prostitution. It was pointed out that several of these disadvantages of increased tourist activity were found in advanced countries and were not confined to the developing nations. This leads, however, to the view that if the bad effects of a new technology have already been recognised in the developed countries, recommendations should be offered to the developing countries on how to mitigate these bad effects before the new technology is introduced there.

Conclusions:

- Australia has played, and can continue to play, an important role in providing technical agricultural assistance to many developing countries, particularly to those with similar climatic conditions.
- Australia should not refuse to supply technological aid requested by a developing country on the grounds of possible unfavourable social and economic effects.
- Basic education and improvements in technical training are crucial if a developing country is to have the ability to make appropriate choices of foreign technology and to gain the benefits from its introduction.
- Multi-national corporations have made a positive contribution to the economic and social development of many developing countries through the technology which they introduced.
- If the bad effects of a new technology have already been recognised in developed countries, recommendations should be offered to developing countries on how to mitigate those bad effects before the new technology is introduced there.

4. POSTSCRIPT

In conclusion, it was apparent from the two days of discussion that the participants were anxious to take practical steps towards mitigating the undesirable economic and social consequences of technological change without losing the benefits that it can bring. There was certainly no complacency, but rather a view that more research was needed involving close cooperation between scientists and social scientists.

THE ECOLOGICAL IMPACT OF SCIENCE AND TECHNOLOGY ON THE INDIVIDUAL AND ON SOCIETY

BY

R.J. MILLINGTON

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In 1967, he joined the US Department of Agriculture and was jointly Professor of Agronomy (Soil Physics) at the University of Illinois. His teaching and research activities included work on gas exchange, energy balance, the structure of turbulence above and within crops, and numerical solutions of coupled ion and water flow in soils and water uptake by plants.

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He is a Fellow of the Australian Academy of Technological Sciences.

1. INTRODUCTION

The subject of the ecological impact of science and technology on the individual and on society could be approached by examining the many events occurring in science and in technology and their antecedents and consequences. An alternative approach, to be used here, is to examine the spectrum of man's activities to see how these have changed over time with discovery and innovation and how these activities have affected our globe.

However, initially, an account as to what constitutes ecology is given, because widely held attitudes to ecology and to environmental issues often cloud its origin and nature.

2. ECOLOGICAL CONCEPTS

Haeckel, a German biologist, is attributed with the first use and definition of the term, ecology, in 1866. He wrote in 1870 - 'By ecology we mean the body of knowledge concerning the economy of nature - the investigation of the total relations of the animal both to its inorganic and to its organic environment; including above all, its friendly and inimical relation with those animals and plants with which it comes directly or indirectly in contact - in a word, ecology is the study of all the complex interrelations referred to by Darwin as the conditions of the struggle for existence.'[1]

Increasing interest in this Darwin-stimulated science of ecology led to the first published text on ecology, the 'Oecology of Plants', by Warming, in 1895[2].

Warming's treatise includes almost all the concepts currently looked upon as comprising ecology. The major omission is an extended treatment of population dynamics. Verhulst's earlier work on population growth had been lost - his formulation of the logistic curve in 1838 lay dormant until the curve was rediscovered by Pearl and Reed in 1920 in the United States. It was not until about this time that attempts were made to analyse fluctuations in numbers and diversity of organisms and that concepts of population dynamics were developed.

What then are the concepts fundamental to the study of organism-environment interaction? Some of the attributes of organisms include growth rate and development; mobility; longevity; adaptability to stress; reproduction; and spatial and temporal distribution. The characteristics of populations of organisms include numbers and density; diversity; growth rates in numbers, rate of change of density; competitiveness; and spatial and temporal distribution.

Some of these attributes are anthropocentric in nature, in the sense that adaptability to stress, diversity and competitiveness are measured in terms of other primary attributes. A population, and the organisms which comprise it, will exhibit a spectrum of variation in these attributes and there are inherent limits in the ability of individuals and populations to adapt to environmental variation.

Defining the environment of an organism or population is not easy. For example, the usual environmental factors considered in plant ecology are climate and soil, and these factors show secondary, topographic variation. Climate and soil are not independent variables since the genesis of soils is influenced by both preceding climate and the present and prior vegetation. Further, components of the hydrologic cycle, for example, rainfall, infiltration into the soil, deep percolation, run-off and evapo-transpiration are illustrative of the dependence of soil-water availability to plants on both climatic and edaphic factors.

The presence of plants themselves modifies the climate about the plants. The term micro-climate carries with it the concept of modification of local climate by virtue of the land cover itself, whether it be plant communities or urban communities.

Since only fit species survive, the existing biota can only have inherited successful survival strategies. These are reflected in the location, density, numbers and individual tolerances to environmental variation. However, it is the catastrophic, one-in-a-hundred-year type of event and the maxima and minima which have the greatest impact on organisms and populations of organisms. Ability to survive is to tolerate daily, seasonal or infrequent catastrophic extremes. Thus, organisms have probably evolved a less than maximum ability to exploit some 'mean' or 'average' environment but an ability to withstand extremes which is the essence of survival strategies.

Ecological success of a species then, is first judged by its continuing presence, achieved through various strategies. Success can be judged also by the net annual increment of living biomass. In the longer term, ecological success is a function of individual mass, the number of individuals per unit area, the area occupied, and time. By these criteria man is an outstanding ecological success.

3. POPULATION GROWTH

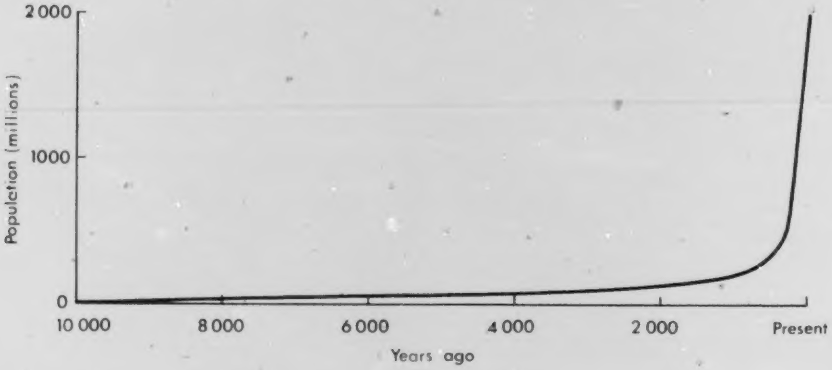
While Homo sapiens' origins (Australopithecus) go back about 2½ million years, the controlled use of fire, as evidenced by hearths, goes back some 300-500 000 years in the Northern Hemisphere. Our more recent ancestors appear to be of this antiquity. Archaeologic records of 30-40 000 years ago for modern man are well dated and widely documented across the world.

Even now, estimation of human populations presents problems and to rely on anything other than historical records may be unwise. Keyfitz[3] has pointed out, with respect to projections of world population, 'the Medium Variant 1980 projection has gone from about 3.3×10^9 to 4.5×10^9 over 17 years. The increase was 36% or about

1.8% per year, a growth (in the estimate) of the same order as the population itself showed over the period of the estimates.' Nonetheless, Figure 1 shows population estimates[4] since 10 000 years BP. The global human population is reputed to have grown at about 0.002% per annum until about the 16-17th century but in the next couple of centuries the growth rate accelerated to the present level of about 2% per annum.

FIG. 1

Growth in human population since 10 000 BP (after Deevey[4])

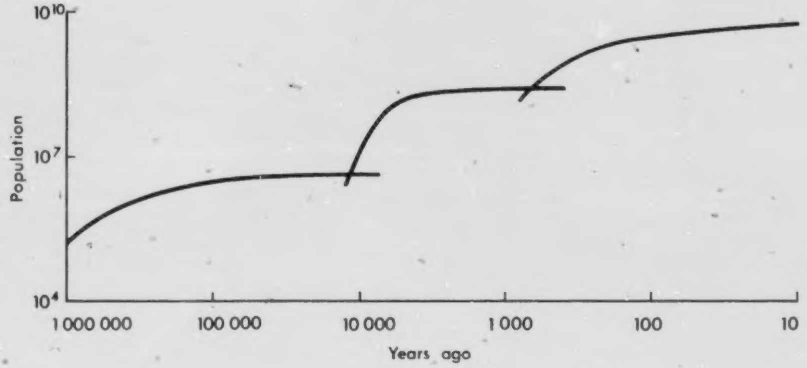


The rapid increase in population growth rate is generally attributed primarily to increasing life expectancy. While this constitutes additional description, it hardly constitutes a reason. In the rapidly urbanising and industrialising nations in Europe, North America and in Asia in the 19th and 20th centuries, such a lowering of mortality rate due to public health and sanitation improvements, as well as to control of some epidemic diseases, seems plausible. However, with their relatively small populations, the growth rates in Europe and in North America in the 18th and 19th centuries had little impact on global population growth. The real growth in population according to Frejka's review[5] was in Asia, where the population was about 0.4 x 10^9 in 1650. Even with a growth rate less than 0.6% per annum until the 1920s, population increased to more than 2 x 10^9 by 1970. With improved control of epidemics and enhanced food production the growth rate over much of Asia, Africa and Latin America is now 2-3% per annum compared with less than 1% in the 1850s. However, the change from 0.002% to 0.6% per annum occurred in the absence of either medical or public health improvements. Could it be suggested that man's rate of evolution with respect to disease immunity out-stripped the rate of change of virulence in pathogenic viruses and bacteria over this period?

Rather than look at population growth as a smooth continuous curve, Deevey has suggested the form shown in Figure 2. The first curve purports to show population growth following toolmaking; the second part, growth following the agricultural revolution; the third part reflects the impact of the scientific-industrial revolution. The first two phases are indicative of the effects of enhanced food supply and the latter of enhanced food supply together with improved community health.

FIG. 2

Suggested course of population growth (log/log) following technological and cultural changes. The three stages follow tool making, the Neolithic agricultural revolution and the advent of modern science respectively (after Deevey[4])



Accompanying the increase in growth rate of population there has been an increase in the proportion of the population in urban environments. Kingsley Davis[6] emphasises that patterns of population distribution are driven by population growth itself. Although towns and cities appeared some 5000 to 6000 years ago, rural dwellers in all nations outnumbered urban dwellers until the last century. In 1800, some 25% of the population of England and Wales and 10% of the US population were regarded as urban dwellers; now the proportions are 80% and 70% respectively. In the first half of this century India's proportion of urban dwellers doubled from 10% to 20%; in Egypt the proportion is currently greater than 40%; and throughout the world the process of urbanisation is accelerating. According to Kingsley Davis,[6] when the world population was 3 x 10^9, some 20% were in cities of more than 100 000 inhabitants. Extrapolating these trends since 1800 gives more than half of the world's population living in such cities by 1990. Australia has always been a highly urbanised society and since the latter half of the last century has been more highly urbanised than the United States.

The total mass flow into an industrialised city of a million inhabitants, including raw materials for manufacturing and construction, is about 10 000 tonnes plus 625 000 tonnes of water per day. Wastes, other than factory wastes, include 500 000 tonnes of sewage and garbage and 1000 tonnes of gaseous and suspended particulate matter. Clearly technology and energy are necessary to acquire these quantities for subsistence, mobility and warmth, quite apart from the additional requirements for manufacturing, building and construction.

How then does one approach the subject of the ecological impact of science and technology on the individual and on society? While the data available on the growth of the human population (itself a measure of ecological success) may not be particularly precise, major changes in growth rate over time and differing growth rates between continents and nations cannot be questioned.

While these variations may be partly due to products of science and technology, it can also be argued that scientific and technological advances are a consequence of demands within human populations because of innate individual instincts to survive. Individual survival and survival of progeny require food and some level of immunity from predators and disease. Increasing numbers and aggregations of individuals pose food and material supply problems and enhanced contagion on one hand but security from predators and the benefits from division of labour on the other. The supply problems were partly met by the domestication of plants 10 000 years ago; the problems of public health and epidemic control a century or so ago; but the full benefits of sustained balance of human activities attendant on the division of labour are yet to be achieved. Security from predation or aggression waxes and wanes as producers and purchasers of technology alter the distribution of technology and its products and thus the pattern of offensive and defensive capability around the world.

The paths of population growth and technology are parallel, but the simplicity of some technological steps belies the magnitude of their impact. Neolithic agriculture enabled increases in population out of proportion to the natural supply of foodstuffs. From that time there was no turning back and developments in technology and in science have made continued population growth possible. However, methods of handling the complex problems stemming from increasing interdependency between individuals and their separate and collective dependence on their biophysical environment have yet to be provided.

The greatest ecological impact on the individual has been through the agricultural revolution. This facilitated population growth and caused competition for resources - the water resources, fuel and non-fuel minerals, and the land on which food and fibre production and all other human activities occur. We have progressed from a simple institutional environment where family units and the small community provided self-correcting, self-imposed, constraints to high levels of interdependency and lack of individual self-sufficiency. Today, a complex system of institutions is required to cope with the material wants and maintenance of the coordinated functioning necessary in large aggregations of individuals.

4. THE NATURE OF MAN'S ACTIVITIES

The range of activities pursued by the inhabitants of a country is somewhat overwhelming. However, the types of activities pursued can be grouped as follows: agriculture (fibre and food production); transportation; manufacturing; mining; communications; housing and construction; health, education and other community services; business and commerce; and recreation. Energy transformation, materials transformation, and information storage, retrieval and transfer are processes common to most of these activities and each occurs within constraints of space and time.

Initially, the spatial and temporal constraints were biologically and environmentally dictated. Mobility was restricted to self-propulsion and time was measured by the sun and seasons. As mankind spread across the earth, maps, calendars, navigation and, later, more precise measurement of time evolved. The location and size of resources and communities, and the means of establishing flow pathways between them, led to the exchange of goods and thus the concepts of measurement of weight and of money.

The fundamental concepts of science, other than some mathematics and early astronomy, mechanics and optics, stem largely from the Baconian era; but technological progress had already occurred without science being formalised. Canoes and vessels were developed in the absence of Archimedes' principles; the steam engine without the laws of thermodynamics; and the distillation of whisky led Joseph Black to develop the concepts of latent heat and specific heat. However, while many technologies and cultural developments took place in the absence of science as we now know it, the 'rate' of these developments was much 'slower' than now. This 'rate' might be measured in two ways - the frequency of innovations and the change with time in the effectiveness with which the innovation performs the task for which it was created. Let us consider some of the processes common to the human activities listed above and see how these processes have changed.

5. MATERIALS TRANSFORMATION

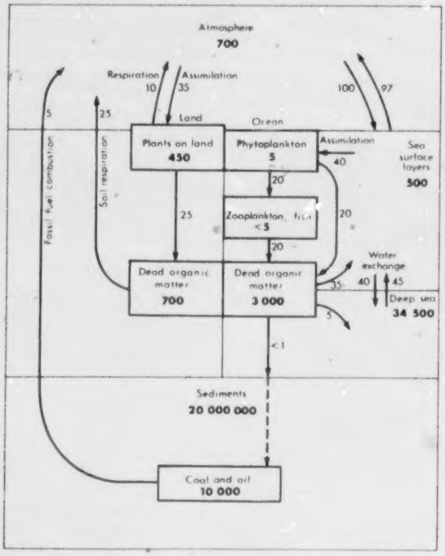
It is generally assumed that over long periods (centuries?) the global standing biomass is in balance with the environment and that annual increments are balanced by death and decay. However, the species composition of the biomass (animal and plant) can change seasonally and in response to shorter- and longer-term fluctuations in the environment. The inherent ability of organisms and populations to respond to environmental change depends, at least in part, on the 'memory' locked in their genetic make-up. This implies that an apparently new set of conditions may have already been experienced during the evolution of surviving species or genera, which thus possess the strategies required to meet the apparently new conditions.

Since all organisms are composed of carbon, hydrogen, oxygen, sulphur, phosphorus and nitrogen (together with lesser amounts of iron, trace elements and a variety of other elements), we can get some measure of man's place in his environment by examining global bio-geochemical cycles.

Figure 3[7] shows that, neglecting the oceanic components, the net carbon uptake by plants is 25×10^9 tonnes per annum and that the standing biomass is 450×10^9 tonnes. The rate of loss from the plants due to death and litter fall is necessarily also about 25×10^9 tonnes. By comparison, the carbon flux through the total biomass of humanity is only 0.15×10^9 tonnes and its biomass only 0.03×10^9 tonnes. However, through combustion of fossil fuel man releases another flux of $6\text{-}8 \times 10^9$ tonnes - about a quarter of that going through the rest of the terrestrial plants, animals and micro-organisms. There is a similar situation with nitrogen. The anthropogenic fluxes due to fossil fuel combustion and fertilizer fixation are the same size as the flow through the terrestrial biomass.

FIG. 3

Global organic carbon cycle Biomass carbon in bold type, annual fluxes in light type. Units, 10^9 tonnes (after Bolin[7]).


Atmosphere
700
Respiration
10
Assimilation
35
100
97
5
25
Land
Ocean
Fossil fuel combustion
Soil respiration
Plants on land
450
Phytoplankton
5
Assimilation
40
Sea surface layers
500
20
25
Zooplankton, fish
<5
20
20
Water exchange
Dead organic matter
700
Dead organic matter
3 000
35
40
45
Deep sea
34 500
5
<1
Sediments
20 000 000
Coal and oil
10 000

With phosphorus, fertilizer production and industries are again responsible for large fluxes, quite disproportionate to the human biomass and 'natural' fluxes through the global biomass.

The location of activity is obscured by using globally integrated data of material balances. Clearly, the mass of material redistributed by man's activities varies widely and local fluxes can be very much greater than in an area uninhabited by man.

TABLE 1

A comparison of natural and anthropogenic rates of mobilisation of crusted elements (after Bowen[8])

Element	Geological rates (river flow)	Man-induced rates
Iron	25 000	319 000
Nitrogen	8 500	9 800
Manganese	440	1 600
Copper	375	4 460
Zinc	370	3 930
Lead	180	2 330
Molybdenum	13	57
Tin	1.5	166
Antimony	1.3	40

(thousands of tonnes per year)

When we consider other crust constituents used by industrialised man, the rates of their mobilisation can be compared with geological weathering as evidenced by the discharge of these constituents in rivers to the oceans (Table 1[8]).

When the products of specific technologies have been examined, major emphasis has been attached to radionuclides, pesticides, including DDT and other halogenated hydrocarbons, phosphorus, nitrogen compounds, petroleum products and their combustion products, and mercury as well as other heavy metals. Many of these materials, gases, liquids and solids are pollutants and their presence led to environmental protection agencies being established in most developed countries.

The dominant disciplined efforts in the field of pollution have been to establish the location and strength of sources, the distribution and persistence of pollutants in the physical environment, and their courses through food chains, to formulate control legislation, and to estimate economic costs and benefits of controlling the release of pollutants.

It is interesting to a scientist that Gutmanis[9] states that 'most economic analyses of environmental issues utilising input-output analyses' can be criticised for their 'failure to include the materials balance of Ayres and Kneese'.[10] He goes on to say that such an 'accounting change cannot affect the relationships already implicit in an input-output model' without a mass balance or mass conservation being satisfied. Despite what appears to be a fundamental deficiency in this method of analysis, Gutmanis estimates that the annual costs of pollution abatement in the United States will grow from a current annual level of 1-1.5% of Gross National Product (GNP) to 3% by the year 2000, and (in 1970 dollars) this is equivalent to $US30 x 10^9 or about $US125 per head. This represents an additional cost to each household which is about the same as the current full medical insurance for a family.

While much attention is attached to undesirable ecological impacts of products of manufacturing industries, research has so far neglected the loss of productive land caused by agriculture itself and the spread of urban land uses. It has been estimated[11] that some 44% of the area devoted to cropping and improved pastures (1.8 x 10^6 km^2) in Australia needs both soil conservation works and restoration by improved management methods. Some 40-50% of the arid zone's 3.36 x 10^6 km^2 needs attention and the situation is similar in the intensively cultivated sugar and horticultural areas. The current cost estimate for these repairs, which result from less than 200 years of land use, is between 0.5 and 1.0 billion dollars. Losses in productive land area due to urbanisation, airfields, roads, etc. are about 80 x 10^6 ha in the US and about 7-8 x 10^6 ha in Australia. However, as there are only 70-80 x 10^6 ha of land suited to the plough in Australia it is clear that urban areas occupy a significant part of a quite limited resource.

In a broad sense, both soil erosion and urban sprawl can be regarded as lateral fluxes of soil and asphalt and concrete respectively and, as such, are processes of material transformation and flow.

Losses of land through salinisation come into the same mass flux category. The pollutants of greatest significance and most widespread occurrence, other than sediment, are the soluble salts resulting from geological weathering. Their redistribution is accelerated following modification of hydrologic regimes by man. Highly productive agricultural lands and water resources are lost for both food production and urban use. These losses are of major concern. A report[12] on salinity in the Murray-Darling Basin showed that the sources of 50% of the salt load in the Murray River cannot be specified. The annual rise in salt concentration of the water at the Adelaide end of the river has been estimated at 6 ppm per annum and water control structures are only of limited use in reducing salinity. It is clear that the potential for land use, both urban and agricultural, in the Murray-Darling Basin requires additional surveying and analysis. It is the pattern of land use, both in extent and intensity, which modifies the hydrologic regimes of the Basin, the salt load of the rivers, and the secondary salinisation of the irrigated areas.

6. ENERGY TRANSFORMATION

Having shown that material flows of human origin are appreciable, and that some are large compared with those through the rest of the terrestrial biomass, the significance of energy fluxes needs examination. Man's activities might be expected to be insignificant on a global scale when compared with the solar energy flux, the circulation of the atmosphere, and the energy balance at the earth's surface in terms of radiant, convected, sensible and latent heat and conduction into and out of the earth itself.

The incoming solar radiation at the outer boundary of the atmosphere is about 340 W/m^2 (watts per square metre), of which about 30% is reflected back (the planetary albedo). Further scattering, absorption and re-radiation occurs in the atmosphere so that the annual net radiation (short and long wave) at the earth's surface is about 100 W/m^2 and for the whole globe 50 000 Terawatts (TW) (TW = 10^{12} W). Of this, about 1000-1200 TW are converted within the processes of the weather. Flohn[13] has estimated that past climatic fluctuations have resulted from, or led to, alterations of 10 to 25% of the energy involved in weather processes.

Currently, combustion of fossil fuel contributes 8 TW to the system and the sum of all anthropogenic effects, including atmospheric carbon dioxide, is 15 TW - about 1/10th of the 100-300 TW variation associated with climatic fluctuations.

While these global figures are surprising, a population increase from 4 to 12 x 10^9 and a per capita energy supply of 8 KW (kilowatts) could result in the contribution from direct combustion rising to the same level as previous climatic fluctuations. If fossil fuel use continues to rise and with continuing deforestation and expanding agriculture, the carbon dioxide concentration should escalate to 2.5-3 times the present level,[13] with concommitant effects on the total anthropogenic flux.

However, these global figures of energy inputs and comparison of their magnitude with global and natural fluxes again give little perspective in a dynamic system noted for temporal variations in gradients and mobility of mass and energy, both laterally and vertically. Global integration cannot deal with the effect of localised sources or sinks on the patterns of transport within the atmosphere itself. Extension of irrigated agriculture and clearing of forests and perennial vegetation result in major changes in the spatial pattern of latent heat flux from the earth and have further effects on net radiation by modifying the earth's albedo. Similarly, with cities and urban areas not only are the usual energy balance components modified but anthropogenic fluxes can reach 100-200 W/m^2.

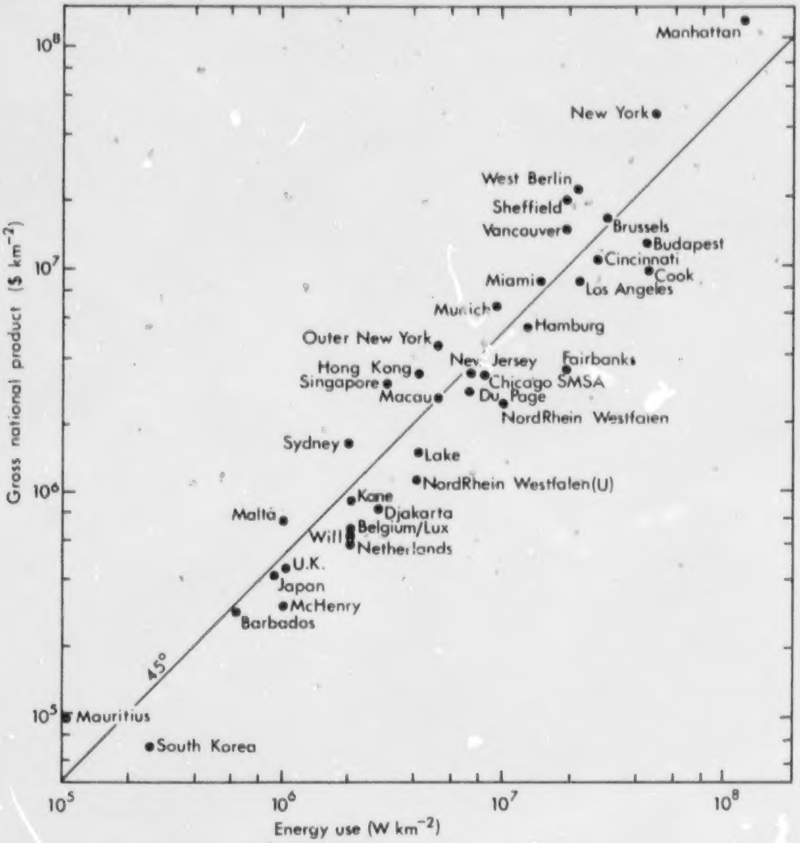
Concepts of energy and work have arisen mainly from substituting alternative means of completing a task. Domesticated animals, hydraulic systems, levers, rollers and wheels have a long history, but it was only when it came to selling Watt's engine that energy and power required formalism and measures.

In an urbanised country like Australia the energy (end use of primary fuels) from fossil fuels is broken up in the following way - transport and storage 30.6%; manufacturing 41.7%; domestic 16.8; commercial 3.9%; mining 4.3%; and agriculture 2.8%.

In cities, the areas of most intense human activity, we find the relation between GNP per unit area and intensity of energy use as shown in Fig. 4. In Manhattan, the energy dissipation at 100 W/m^2 is the same as the net radiation. Other data of Kalma et al.[15] show that the spatial variation within a city, and for parts of the day during particular seasons, is the same in Sydney as in Manhattan.

FIG. 4

The relation between gross national product and energy use per unit land area (after Kalma and Millington[14])



One hundred and fifty TW are involved in the integrated annual latent heat flux from irrigated agriculture and are distributed over an estimated area of 2 x 10^6 km^2, giving a latent heat flux of 75 W/m^2. The latitudinal variation in climate and the occurrence of one to three crops per annum will lead to spatial variation in latent heat fluxes of 50 to 150 W/m^2. In referring to Flohn's work above, it was pointed out that spatial variation in energy sources and sinks is the basis of atmospheric circulation. In addition, the altered balance between radiation, sensible heat and latent heat fluxes resulting from irrigation is as important a consideration as the total flux itself.

Global water withdrawals are expected to rise from a 1965 level of 2848 km^3 per annum to 12 700 km^3 per annum in 2000 AD. The return flows in each case are 1050 and 7790 km^3 per annum. Irrigation is expected to increase from 2 x 10^6 km^2 to almost 4 x 10^6 km^2 and 'a substantial acceleration of the hydrological cycle will take place'.[16] The use of water in irrigation can be compared with the total precipitation on the continents of 108 000 km^3 per annum and total run-off of 37 000 km^3 per annum. On the other hand, it can be looked upon as the means by which the maximum surface temperature of the projected 4 x 10^6 km^2 of irrigated lands will be significantly decreased. Climatic model computations by the Australian Numerical Meteorology Research Centre (ANMRC) show quite remarkable changes in weather patterns if the sea's surface temperature changes 1°C over 1 x 10^6 km^2. It could be expected that similar effects would result from changes in land surface temperatures over similarly large areas.

Agricultural land use has already resulted in changes to the albedo and the ratio of latent heat to sensible heat fluxes over 40% of the land surface, and it has been forecast that agriculture might eventually occupy about 66% of the land surface. However, this estimate is based on data available in 1967[17] and, at least for Australia, the area available for sown pastures or arable cropping was seriously in error. An analysis of FAO data from 1951 to 1969 suggests that the area used for managed plant communities might not change greatly from the present level.

We have then two major sources of change to the spatial and temporal pattern of the energy balance at the earth's surface. The urban areas constitute islands from which emanate additional sources of energy released from fossil fuel combustion at rates comparable with the net radiation flux. Further, agricultural land use, which now occupies 40 to 55% of the land surface, has altered the balance between sensible and latent heat fluxes. With irrigation, the average maximum temperature reached is lowered and the average minimum raised.

A large part of the extension of agriculture in both temperate and tropical areas is at the expense of deciduous and evergreen forests. Integrated over the earth's surface, the annual accretion of carbon[18] is about 30 x 10^9 tonnes by forest and woodland over 40-50 x 10^6 km^2. The residence time of carbon is quite different in forest and agricultural systems and, with forest clearing, it is believed that significant additions have been made to the atmospheric carbon pool of carbon dioxide. Also, because the balance between fixation and retention of carbon in the biomass is so different between the two systems, the turnover of atmospheric/organic carbon is accelerated and this effect also leads to increases in the atmospheric carbon dioxide concentration. With agricultural land now equivalent to about one third of forest and woodland area, and a standing biomass in the latter of some 1000 x 10^9 tonnes, it could be suggested that about 300 x 10^9 tonnes of carbon have been released. This can be compared with the atmospheric pool of 680 x 10^9 tonnes and a release of carbon from combustion of 4 x 10^9 tonnes in 1970.

Tied intimately, then, to global and local energy balances are not only the direct effects of energy production, altered albedo, and balances of latent and sensible heat fluxes, but also the effects due to enhanced carbon dioxide concentration in the atmosphere, as well as particulates.

There is no argument about climatic change or climatic fluctuations occurring in the past. There is adequate palaeontological, archaeological, biological and isotopic evidence to convince the most sanguine. The uncertainties currently exercising the scientific community are how fast do changes occur, in what direction, in terms of greater or lesser temperature and precipitation regimes, and, lastly, what activities of man might trigger or accelerate climatic change or climatic fluctuations.

The increase in varve clay thicknesses in the Black Sea over the last 4000 years[19] give evidence of the effect of spreading agriculture on the stability of landscapes draining into that sea. Similarly, the increase in particulates and carbon dioxide in the atmosphere can be regarded as evidence of man's impact through fossil fuel combustion. The consequences of such additions to the atmosphere can be debated, but it would be extraordinary if there was no effect at all, in view of the properties and the increase in mass of these materials in the atmosphere. The different time-scales of actual observations and prehistoric trends make analysis difficult. While non-anthropogenic components of the system seem to indicate a global cooling, the full expression of the effects of increasing carbon dioxide can be masked. Likewise, with decline in ocean temperatures and increased solubility of carbon dioxide, the present one third to half of combustion carbon dioxide which disappears into oceanic solution could change significantly with warming following a rise in atmospheric carbon dioxide concentration. The role of particulates is similarly confused since little attention has been paid to vertical distribution of particulates. In the stratosphere and troposphere the effect of particulates should compensate for the effect of carbon dioxide - that is, a lower surface temperature of the globe. However, an increase in particulates in the lower atmosphere could be anticipated to produce an opposite effect.

With continuing population growth and dependence on coal for energy, there is no doubt that the level of atmospheric carbon dioxide and particulates will increase. At this stage there is no unequivocal evidence as to the consequences of such increases.

7. LIMITS ?

Computers have allowed large amounts of data to be stored and retrieved, as well as large numerical models of complex systems to be designed and analysed. Numerical meteorological models with many layers, many cells, many parameters, and many processes can now be considered. As well, the model system can be run over varying time-scales and periods, enabling the performance of complex systems to be analysed.

Forrester[20] was the first to attempt to model the dynamics of human population growth in relation to material, institutional and economic factors. Later, 'Limits to Growth'[21] followed as an essay on the model, which was, 'like every other model, imperfect, over-simplified, and unfinished. We are well aware of its shortcomings...'. At the time, the scientific community gave the world model a mixed reception because of the deficiencies stated by the authors themselves and because the nature of forecasts, projections and predictions was confusing.

However, the kind of work of Forrester[20] and Meadows *et al.*[21] (which paralleled early work in ecology in the 1960s on soil-plant-atmosphere systems) has grown. Despite continuing, and justifiable, apprehension concerning the validation and methods of testing of large numerical models, the so-called 'systems techniques' are the only ones which can analyse complexity.

The second essay of the Club of Rome, 'Mankind at the Turning Point',[22] illustrated the significance of spatial disaggregation of the model. However, with only ten geographic-developmental sub-systems, the effects of local variation in population density and human activities are obscured.

Ecologists have usually considered the stability or otherwise of ecosystems. The most stable systems are those with high species diversity, complex food webs, small populations of the constituent species, and a net production of zero. In unstable ecosystems, which pass through successive developmental communities (successional stages), the species diversity is usually less and disruption of a part of the system is associated with major repercussions. As quoted by Bourne,[23] 'Nature achieves stability through diversity and complexity'. He believes that the 'origins of man's success must lie in his utilisation of successional ecosystems' and 'to maintain a large (human) population it is not in man's interest to let the ecosystem mature'.

We have two apparently confounding concepts of complexity of systems. With so-called natural ecosystems, we think of complexity in terms of the multiplicity of organisms, pathways and many interlocked flow processes, but with alternative organisms or processes always ready when one of the many much smaller sub-systems fails. In the primarily anthropogenic systems we have monoculture of crops over extensive areas, application of the economic principle of increasing returns to scale in manufacturing industries, in transportation and in other public utilities like water and power supply. These larger and larger centralised capabilities are all indicative of systems structures which have analogies with unstable, successional ecosystems.

To simplify food production, manufacturing, public utilities, transportation, and tertiary service systems it is necessary to coordinate these systems to match supply with demand. Intuitively one might say that coordinating diverse human activities at low levels of population is less complex than at high levels of population. It could be further suggested that rapid population growth in the last two centuries has outstripped the technological innovation needed to coordinate the necessary control systems which must successfully interlock the component individuals, communities and activities of anthropogenic ecosystems. In 'natural' systems the controls, often harsh when viewed by man, have evolved with the organisms themselves over orders of magnitude of millennia. In anthropogenic systems, the impact of population growth is so recent, and has been so rapid, that it would be arrogant to assert with confidence what we have the technologies in hand to ensure the well-being of all members of the present large human population - let alone those who will follow.

The kind of complexity now facing man has arisen from population growth and the attendant advances in separate technologies which cope with sectoral or regional problems. Warfield and Hill[24] state, '..... it is the kind of complexity that is found, for example, in trying to induce growth in a developing nation, in trying to develop effective legislation to deal with poverty, in seeking positive approaches to keeping world population compatible with the capacity of the natural environment ...'. We have developed techniques or technologies apposite to the solution of one kind of problem, but the nature of the links of interdependency need recognition to anticipate consequences elsewhere in the system. It is the 'kind of complexity occasioned by a multiplicity of relations among poorly defined objects or concepts'.

In anthropogenic systems, then, we have relatively few species - man himself, a few domesticated animals and plants - and a trend towards bigger units of production or supply for urban populations whose number, size and density are increasing. One can question the purpose of such a course, but not the need for effective methods of analysis of human ecosystems comparable with those which have developed as the sciences of plant and animal ecology. At least one plausible but neglected limit to growth is that limit imposed by failure to develop comprehension of the structure of complex systems, since this is a first requirement for the design of control systems to ensure continuance of operation of a complex system.

8. CONCLUSION

That there are limits to the concentration of human beings and hence their activities and the resultant energy and mass fluxes into and out of these concentrations is not arguable. That there is a limit to the numbers of human beings on earth, no matter what form or size of aggregations they are in, is again not arguable. There are limits to the rate at which resources can be made available to man and the rates at which he can dispose of or recycle his inevitable wastes. These limits, as for any population of organisms, are functions of the environment on one hand, and the organism's inherent or learned behaviour on the other.

Science and technology have been able to shift these limits with each new demand arising from population growth. Although the consumption of resources may be regulated by economic considerations like price, no supply of dollars can, for example, alter the latent heat of vaporisation of water. The cost of desalinating sea water may be an economic constraint, as it is for recovering phosphate from basalt or granite. With phosphorus, the chemically and physically determined rates of its flow through the delicate pathways of the soil and its clay minerals, through plants and animals including man, and through adenosine phosphate storage and transfer systems, will dictate the biomass of the earth. Man can intervene, and there is demonstrable evidence of his intervention already, but the laws of physics and chemistry cannot be cheated; mass and energy conservation laws apply equally stringently in both 'natural' and anthropogenic systems. Wastes and pollutants will always result from production and consumption and increasing energy needs must be met to maintain the human ecosystems which have developed and are developing.

We can look back at towns and cities deserted over the last few millenia and at the adjacent lands which once supplied their food. It is salutary to find few, if any, of the plants which once formed the basis of subsistence. A deserted wheat farm on the Willochra Plain in South Australia carries few plants of wheat. Without maintenance, the productive systems engineered and supported by man revert to low productivity and the domesticated crop plants, depending on their breeding systems, tend to revert to the 'wild', low-productive types. The key to maintaining human populations, at present and anticipated levels, lies in energy availability and the simultaneous dissipation of this energy in productive systems which are consistent with the resilience of the global environment to withstand such energy generation and material transformation.

Darlington,[25] referring to the 19th century works of George Perkins Marsh on the 'Earth as Modified by Human Action', states that 'every new source from which man has increased his power on earth has been used to diminish the prospects of his successors. All his progress has been at the expense of damage to his environment which he cannot repair and could not foresee. Surely this is the most practical of all the lessons of history. But only if we are able to assess the extent to which this damage has altered the past course of events in order to foretell how such damage may alter the future course of his evolution'.

Science and scientific knowledge have an anticipatory function. They provide the framework of principles whereby the ecological consequences of coupled growth in population and in technology can be met.

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THE IMPACT OF SCIENCE AND TECHNOLOGY ON HEALTH - AN AUSTRALIAN PERSPECTIVE

BY

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Dr Hetzel is the author of *Health and Australian Society* and has been particularly interested in preventive medicine, nutrition and the health of Aborigines. In 1971, he delivered the Boyer Lectures for the Australian Broadcasting Commission. In 1978, he was editor of a book entitled *Basic Health Care in Developing Countries* for the International Epidemiological Association and Oxford University Press. He has been a regular visitor to and consultant in South East Asian countries since 1960 and is currently Deputy Chairman of the International Epidemiological Association.

INTRODUCTION

Over the past century there has been a very substantial improvement in the health of the Australian people. This improvement is due to the impact of science and technology. However, the connection is not a simple one. The impact up to 1940 was dependent on education, nutrition, and environmental changes through better housing, and better quality of food and water. Since 1940, the improvement has been less striking in spite of many medical advances in science and technology, including antibiotics, drugs and modern surgery. This latter period therefore raises questions as to the direction of the medical science and technology - whether in spite of its achievements, it could not be more appropriately deployed to produce better results for the health of all the people. This Australian situation is described in the first section of this paper.

Since the last war, Australia has had special responsibility for Papua New Guinea. Up to 1976, when independence was achieved, many Australians worked in a colonial-type health service in New Guinea. These included many medical graduates who encountered the health problems of this small, tropical, developing country and applied to them the insights from Western medical science and technology. Substantial improvement of health was achieved. However, evaluation now reveals a new situation requiring a different solution - a situation resembling more closely that of Australia than it did before. Solutions to these problems require a rather different approach than in the past, as is also the case with Australia itself. As similar changes are occurring in other developing countries these problems are considered worthy of detailed consideration.

This leads on to consideration of the way in which health improvement is brought about and how it may be expedited. There is a big gap between knowledge of science and technology and its application. It is most obvious in the case of developing countries, but is also true of developed countries like Australia. One example is the delay in the implementation of measures designed to control cigarette smoking in Australia, as in other Western countries. There is now evidence of a major commercial effort to market cigarettes of high tar content (no longer acceptable to most Western countries) in developing countries. We are here led to consider political, social and economic factors in relation to the application of science and technology. Health improvement is essentially a social process requiring a consideration of the problem of technology transfer. This will be discussed in the third section.

To summarise, this paper will review the impact of science and technology on health from an Australian perspective in three parts:

(1) Australia's health status 1880-1975.

(2) Changing health problems in Papua New Guinea.

(3) A consideration of the gap between knowledge of science and technology and its application.

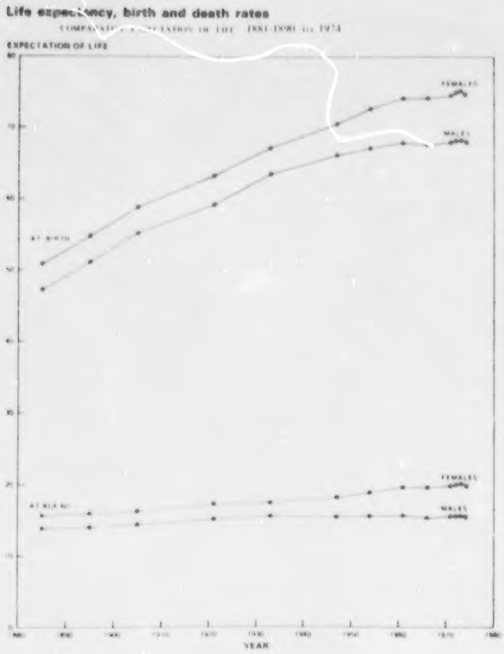
1. AUSTRALIA'S HEALTH STATUS 1880-1975

The striking improvement in expectation of life at birth in Australia since 1880 is shown in Fig. 1 In 1881-90, the expectation of life at birth was 47.20 yr for males and 50.84 yr for females. In 1974, the respective figures were 68.01 yr for males and 75.03 yr for females.[1] However, there has been little improvement in expectation of life at the age of 60 years. It is apparent that the curve shows a constant slope up to 1950, since when, by contrast, there has been almost a plateau. The plateau is particularly striking in the male, although also evident in the female, so that the gap between the male and female life expectancy is greater now than it was at the end of the 19th century. Similar changes have occurred in other countries of the Western world. This plateau in life expectancy has occurred at a time of greater therapeutic efficacy in terms of drugs and other technology available than ever before. In fact, the plateau has coincided with the 'therapeutic revolution'.

Improvement in infant mortality rate (deaths in the first year of life per 1000 live births) has been the major factor in improved life expectancy at birth. Most of this improvement had been achieved by 1940. This is indicated by a rate 38.4 per 1000 in 1940 compared to 103.6 per 1000 in 1901. The major causes of death in the first year of life in 1900 were intestinal and respiratory infections, and the fall in infant mortality is almost entirely due to a fall in these conditions. Few of the specific therapies in use today for treatment of these infections were available by 1940; for example, penicillin was not available in Australia until 1944. This fall in infant mortality must be attributed to 'non-specific' factors such as better education and improvement in nutrition. Better housing and control of water supply through sanitation have also played some part.[2][3] Similar falls in infant mortality rate have occurred in all countries in the Western world over the same period.

Under-privileged minorities can cause significant differences within a country and this applies to the Aborigines in Australia. The Aborigine' infant mortality was as high as 131 per 1000 in Central Australia (Table 1) as late as 1967 associated with poor living conditions and defective diet.[4] The Aboriginal community demonstrates vividly a great lag between knowledge and its application for the benefit of a minority in contrast with the majority. This question is taken up further in the third section of this paper.

FIG. 1



Change in life expectancy in Australia since 1880, showing the contrast between the great improvement in life expectancy from birth and the relative lack of improvement at the age of 60 years. The 'plateau' since 1950 in life expectancy at birth is also clearly shown - evident in both sexes, but more striking in the male, leading to a greater difference between the sexes in 1973 than in the 1880s (reproduced from the Report of the Director-General of Health 1974-75)

TABLE 1

Infant Mortality Rates, Northern Territory Aborigines[4]
(Deaths in first year per 1000 births)

Northern Territory (full-blood) (1965-67)	131
Australia (1958-60)	20.7
NZ Maori (1958-60)	51.0
US Indian (1959)	47.0
South Africa (coloured) (1959)	120.0
India (rural) (1958-59)	145.9

It is also noticeable that in Melbourne in the 1960s it was possible to demonstrate in inner urban areas three times the infant mortality rate seen in outer, more prosperous, areas.[5] These differences correlate with difference in education status.

Let us now consider the major causes of death in Australia today. These are itemised in the Report of the Director-General of Health for 1976-77.[6] The mortality pattern or profile for 1975 is characterised by three major causes: heart disease 36.08%, malignant neoplasms 18.67% and cerebrovascular disease 14.0%. There are a number of minor groups, ranging from 1.01% for cirrhosis of the liver to 3.69% for bronchitis, emphysema and asthma. The malignant neoplasm group includes 3.67% for cancer of the lung and 6.07% for cancer of the digestive organs. 6.2% are due to accidents, of which the majority (3.47%) are traffic accidents. The most important single cause of death is ischaemic heart disease (30.02%).

It is obvious that these various conditions have caused death because suitable remedial measures were not available. In general, coronary heart disease cannot readily be reversed once it has become clinically apparent, although the commonly performed coronary bypass operation, where a piece of leg vein is used to bypass the obstructed coronary vessel, is producing some encouraging results. However, the outcome of careful scientific assessment by controlled trials has still to be reported.

In the case of cancer of the lung and breast, current results of treatment with surgery and radiotherapy are discouraging and have not improved significantly for many years. However, there is evidence of recent improvement in the treatment of lymphomas, leukaemia and Hodgkin's disease with chemotherapy. Treatment for the common alimentary cancers is often unsatisfactory and has not significantly improved for many years.

The major advance in relation to stroke is its prevention by adequate treatment of hypertension. Once brain damage has occurred little can be done.

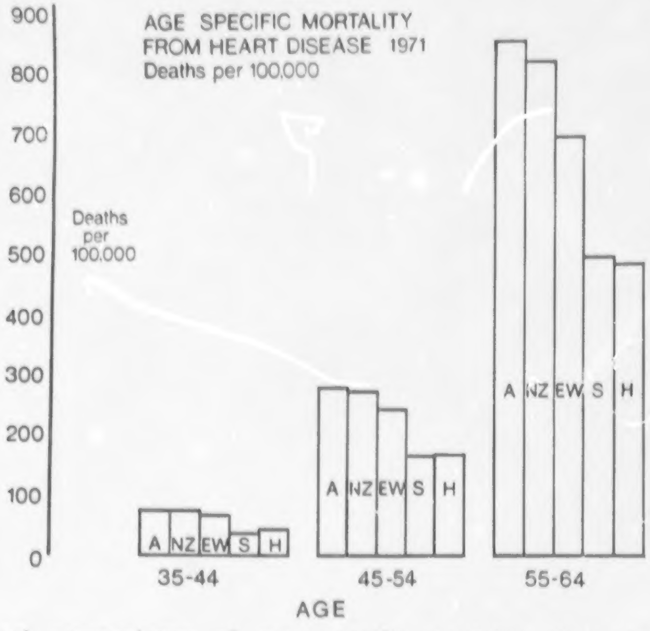
Difficulties in the application of technology to these various medical problems are the reason for the plateau in the curve of life expectancy since 1950. It should be noted, however, that this period, characterised by such limited health gains, is associated with greater expenditure on health services than ever before. Per capita expenditure has increased from 5.2% of gross domestic product in 1963-64 to 6.0% in 1972-73 and to 7.4% in 1975-76. These costs are causing great concern to the Treasury and the Government and various measures to reduce expenditure have been introduced.

However, it is very important to recognise that while curative technological measures have severe limitations, there is much evidence indicating that prevention is possible. This applies to coronary heart disease, lung cancer, cirrhosis of the liver and other chronic liver conditions.

In coronary heart disease, stopping smoking has been shown to reduce mortality to virtually that of the non-smoker after 10 years.[7] The same applies to lung cancer[2] and to other chronic respiratory conditions such as bronchitis and emphysema. Reduction in alcohol consumption reduces mortality from cirrhosis of the liver.[2]

It is of interest to make international comparisons between different industrialised countries. Such a comparison for the incidence of ischaemic heart disease as a cause of death in 1971 is shown in Fig. 2. It will be seen that the differences between Australia and New Zealand on the one hand and Sweden and the Netherlands on the other are evident in the 25-34 age group, but become more striking in the 45-54 and 55-64 age groups. England and Wales occupies an intermediate position.

FIG. 2



International comparisons of age specific mortality from ischaemic heart disease for 1971. Australia (A), New Zealand (NZ) and England and Wales (EW) have higher rates than Sweden (S) and Holland (H). Data from World Health Statistics.

The question posed concerns the reasons for these differences. Four major factors could be relevant: human biology, environment, life-style and health services as suggested by the health field concept of Lalonde.[8] I have discussed this matter in more detail elsewhere,[9] but my conclusion, based on analysis of each of these possibilities, is that variations in life-style are probably the major reasons for these differences. While biological factors cannot be denied, it would seem again that differences in life-style are the most potent cause of the increasing differences in life expectancy between the sexes (Fig. 1).

Australia and New Zealand have very similar mortality rates in spite of the difference in the organisation of their health services. But they are characterised by a similar life-style and social environment with higher alcohol and cigarette consumption than, for example, Norway, Sweden and the Netherlands. These lower levels reflect a greater degree of health awareness due, at least in part, to long-established health education programs.

This discussion has revealed the limitations of applications of science and technology in relation to the improvement of health in Australia. Factors such as education, economics and politics and general standard of living are all highly relevant to technology transfer. However, big improvements have occurred in health in Australia based on both science and technology and the transfer of the benefit through mass education and the mass media. But a new situation has now emerged which calls for more research in the social and behavioural area, particularly directed to the effects of the social environment on health and in the realm of community education.[9][10][11]

2. CHANGING HEALTH PROBLEMS IN PAPUA NEW GUINEA

The physical environment of Papua New Guinea - a tropical country with rugged and high mountains, forests, rivers, and vast swamps - resembles that of many developing countries in the tropical belt of the world. Its health problems are also similar, with a high level of infectious diseases (pneumonia, gastroenteritis, and malaria), malnutrition, and rapid population growth.[2][12]

The contrast between the health problems of Papua New Guinea and those of Australia is shown in Table 3. The higher birth rate and death rate in Papua New Guinea are associated with much higher infant mortality rates. Natural population increase is 2.7% compared with 1% in Australia. The greater prominence of infectious diseases in Papua New Guinea is obvious compared with the Australian profile. The comparison of dietary intake in Papua New Guinea and Australia shows the much lower protein and fat intake in Papua New Guinea. This is associated with slower growth in adolescence - adult stature is usually not achieved till the age of 24 in males and 18 years in females.

TABLE 3

Population Statistics[12]

Age	Papua New Guinea	Australia
Less than 15 yr	43.6%	29%
Birth rate	42/1000	19/1000
Death rate	15/1000	9/1000
Infant mortality rate	85/1000	18/1000
Population increase	2.7%	1%

Dietary Intake*

Total energy	9600 kJ (2300 kcal)	13 250 kJ (3165 kcal)
Protein	3%	15%
Fat	2%	42%
Carbohydrate	95%	43%
Salt	0-5 g/day	5-15 g/day
Coronary Heart Disease	Low	High
Hypertension	Low	High
Diabetes	Low	High

* Composite data from various sources, CSIRO Division of Human Nutrition

Causes of Death[12]

Papua New Guinea		Australia	
Pneumonia	45%	Heart disease	36%
Gastroenteritis	12%	Malignant neoplasms	18%
Dysentery	10%	Stroke	14%
Meningitis	8%	Bronchitis	4%
Malnutrition	5%	Motor vehicle crashes	4%
TOTAL	80%	TOTAL	76%

Coronary heart disease is rare in Papua New Guinea, in contrast to its very high incidence in Australia. In Papua New Guinea, blood pressure does not rise with age as in Australia - high blood pressure is uncommon in Papua New Guinea, in contrast with its high prevalence in Australia (where it affects up to 20% of the population). The low intake of fat and salt are considered to be major factors in bringing about these differences.[12]

Since the Pacific War, Papua New Guinea has developed a comprehensive and effective public health service, with a strong emphasis on prevention. Considerable progress has been made with the control of malaria, tuberculosis, and leprosy, as well as other infectious diseases. The basis of the health service has been the aid post orderly (APO), who looks after an average of seven villages, about 1000 people in all. In 1970, there were 1500 of these men moving between the villages on foot - the only possible method of transport in the mountainous terrain.

Comparison between the national mortality rates of 1952 and 1967 reveals a 54 per cent fall in deaths due to malaria, bacillary dysentery, and tuberculosis.[13] There was a fall of 22 per cent in deaths due to pneumonia, meningitis, leprosy, and gastroenteritis. These improvements can be attributed very largely to basic health care at the APO level. APO training consists of two years as a hospital orderly, including training in preventive aspects. Trainees have usually had at least a primary school education.

An example of technological innovation in Papua New Guinea is the control of severe dietary iodine deficiency with the injection of iodised oil. A single injection has been shown to correct the severe deficiency for nearly five years.[14] Its value in the prevention of goitre and brain damage (cretinism) has been established.[15][16] This measure is particularly appropriate for the correction of iodine deficiency in people living in remote mountain villages, in contrast to the more conventional iodised salt, and is now being used extensively in other developing countries in South America, Africa and South East Asia.

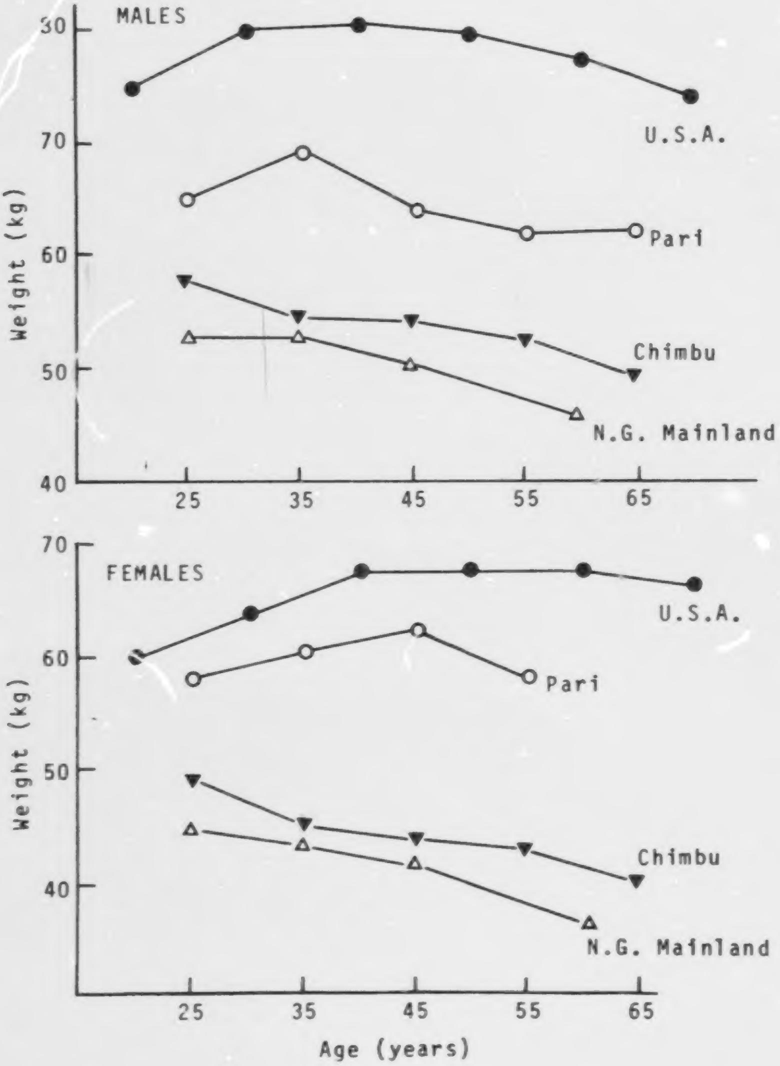
The impact of modern advances in science and technology on the Papuan village of Pari has been well described by Maddocks and Maddocks.[17] This village, situated only 3 kilometres from the administrative capital of Port Moresby, has virtually become a suburb. Reticulated water, telephones, electric power and a sealed road were all connected to Pari in the early 1970s. However power charges, water rates, school fees, and building regulations all cut across the traditional regulation of affairs through a village meeting and consultations within the network of interpersonal and interfamily obligations.

In fact, health itself is now seen as something 'achieved' from 'outside' the village - improvements in water supply, control of malaria, and immunisation procedures all come from outside the village and are no longer the prime responsibility of the village community itself. At the same time, the pattern of illness is changing with these social changes and change of life-style. Obesity, elevated blood pressure and diabetes are all now in evidence and are associated with consumption of an Australian-type diet and a more sedentary way of life.

Indications of this change are provided by measurements of body weight and serum cholesterol. The increase in body weight in both males and females in the village of Pari in contrast to that in the whole New Guinea mainland population and the Chimbu (a New Guinea highland population) is shown in Fig. 3. Data from the USA are also shown for comparison. Suitable figures for the Australian population are not available, but are likely to resemble those of the USA population.

FIG. 3

Body weight by age of males and females in populations of Pari, Chimbu (New Guinea Highlands), the New Guinea mainland region, and USA.[17]



Increases in serum cholesterol levels have been clearly associated with these increases in body weight.[17][18][19] These differences in serum cholesterol indicate the likelihood of the development of coronary heart disease in those populations whose life-style is changing from the traditional pattern.

It is becoming clear that this pattern of ill-health cannot be met simply by an extension of special services 'from outside' the village. It requires a health information and education campaign based in the village, though it will need to draw some resource material from outside. It requires a degree of community organisation and self-responsibility which will establish a more responsible and active approach to health followed by appropriate application of the benefits of science and technology.[20]

The need for this almost revolutionary approach has been recognised by the World Health Organisation (WHO) and UNICEF in a recent joint statement.[21] The statement recognises that high-cost, technological, curative medicine with its complex of drugs, doctors and hospitals has been far too dominant in developing countries. The effect of this domination has been to confine health care to those that can afford to pay for it - less than 20% of the population in developing countries.

The joint WHO-UNICEF statement stresses the need for health education for improved self-care, community participation, prevention rather than cure, environmental sanitation, provision of food and clean water, and the use of village-based health workers with appropriate technologies. Village health workers are necessary because most diseases can be identified and cured by simple technology, including diagnostic tools, antimalarials and simple treatments (antibiotics). The use of cheap methods of refrigerated transport is also a great benefit for the carriage of vaccines and other supplies.

The Mahler-Labouisse statement points out the aim should now be: '... to make the community the focal point of the whole health system; to look for the relevant technology that countries and communities can accept and afford.'

3. THE GAP BETWEEN KNOWLEDGE AND APPLICATION OF SCIENCE AND TECHNOLOGY TO THE IMPROVEMENT OF HEALTH

We have already shown how health has improved in Australia over the past century. This improvement was particularly striking up to 1940, but has not been so striking since. However, within Australia the Aboriginal minority has failed to benefit along with the majority of the Australian population, as indicated vividly by the very high infant mortality.

(a) Aboriginal Health

Prior to 1969, Aboriginal health was known to be poor by only a limited number of people in direct contact with the problem. Our present-day serious concern about the situation of Aboriginal health in Australia dates from the publication of data on infant mortality for full-blood Aboriginals in the Northern Territory by Moodie in 1969 (Table 1). The publication of these data, and their wide dissemination, led to discussion and a much greater concern about the whole problem of Aboriginal health. The data were a major stimulus to new initiatives adopted by the Government in the early 1970s.

A national seminar on Aboriginal health held at Monash University in May 1971, attended by 70 participants including 26 Aborigines from all over Australia, was influential in determining broad guidelines for the health improvement of Aborigines.[22] These guidelines were subsequently used in defining a new strategy for the problem after 1972.

In 1976, a workshop involving some 12 CSIRO Divisions, the Department of Aboriginal Affairs, the Department of Health and the Australian National University was held around the general theme, 'The Nutrition of Aborigines in Relation to the Ecosystem of Central Australia'. A series of papers concerned with nutrition, food resources, land development, wildlife, water supplies, current problems of crop production, and future developments were presented and have been recently published.[23] Subsequently, in 1977, a follow-up workshop in Alice Springs included consultation with the Central Land Council.[24] These discussions have revealed the great gap between the knowledge available and its application for the benefit of Aboriginal communities. The major need is for extension services to bridge the gap, and steps are now being taken to provide these by a coordinated effort involving CSIRO, the Department of Aboriginal Affairs, and Northern Territory departments.

(b) The Compulsory Wearing of Seat Belts

In contrast to the great lag in the application of science and technology to the health and welfare of the Aboriginal community, the use of seat belts in road vehicles represents the successful application of science and technology.[25]

In 1970, a mounting road toll in Victoria was a matter of general community concern. Statistics on road deaths and road injuries were being regularly provided through the newspapers. The possibility of reducing road deaths and injuries by the compulsory wearing of seat belts was suggested by experience in the Snowy River Hydro-electric Project, where the compulsory wearing of seat belts by tractor drivers had significantly reduced deaths and injuries due to accidents. There were also data from the Volvo Factory in Sweden and the Cornell Laboratory in the USA indicating the benefits of the wearing of seat belts. These data were made available to mass media and the Victorian Parliamentary Select Committee on Road Safety and culminated in the proposal that the wearing of seat belts should be made compulsory in Victoria. The Government of the day hesitated for some months because of doubts about the possibility of enforcement of this legislation, but finally towards the end of 1970 the legislation was passed and became law in 1971. Immediate steps were taken to collect data in the first nine months of 1971 on road deaths and injuries in Victoria and it was possible to make a comparison with the previous year, the first nine months of 1970, between Victoria and the rest of Australia. The data showed a reduction of 17.7% in occupant fatalities and 14.8% in occupant injuries and provided clear evidence of benefits, which resulted in adoption of the legislation in the other States of Australia in rapid succession. The evidence also resulted in passage of similar legislation in the Netherlands, Belgium, France outside of Paris, and Sweden by 1976.

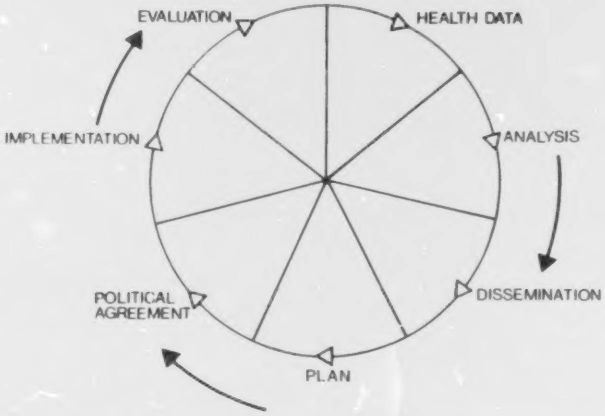
(c) A Model for the Social Process of the Application of Science and Technology to Health

The two case studies presented indicate an interplay of several components in the social process involved in the application of science and technology to health. The components include the collection of epidemiological data, the dissemination of these data so that the community becomes aware of the situation, and political action; implementation and evaluation then follow.

A model of this social process has been suggested for an analysis of these two case studies and other recent developments in the health scene in Australia.[26] This model shown in Fig. 4 indicates a process involving a series of seven steps.

FIG. 4

MODEL



A model of the social process of health improvement (reproduced by permission of Oxford University Press)[26]

The process begins with the collection of data related to health status, including morbidity and mortality data. The next step is analysis and careful consideration of the meaning of the data. The third step involves dissemination, not only through the scientific community but, even more importantly, through the mass media to the community at large. Eventually a plan emerges from discussion between the community and the epidemiologists, administrators, and other professionals. The plan then has to receive political agreement, which often requires community consultation with various groups. Implementation can take place following the achievement of political agreement. After implementation must come evaluation, which involves collecting more data to provide the basis for review of the plan and necessary modification in the light of experience.

In the case of the seat belt legislation, this process has gone full circle, culminating with implementation and evaluation as already described. However, in the other instances of life-style and behaviour related to health, the social process is blocked at the level of health data collection and analysis. Systematic dissemination to the community has barely begun and the limited dissemination that has already occurred is far outweighed by mass media advertising.

In spite of political and economic obstacles, television advertisements of cigarette smoking have now been abolished in Australia (since September 1976). Cigarette smoking increased in women and in young people, particularly in girls, between 1971 and 1974 in spite of active health education campaigns. Alcohol consumption has also increased in young people including the better educated in high income groups.[27] These data indicate the need for much more research into health behaviour, including the motivation for alcohol consumption and cigarette smoking within the framework of social learning. The importance of young adult life-style relative to health in middle age is now apparent, but poses a new and difficult problem for preventive medicine. Young people need to understand and accept this difficult and unwelcome concept in a commercialised and affluent society which is keen to exploit them and the big market they represent.

Serious attempts at health education in schools have now begun in Australia. In South Australia a task force has been established, with a special intensive program for training experienced teachers who then return to their schools to initiate programs. This program is likely to spread to other States. However, efforts at health education by health professionals are still very limited. Responsible press and television coverage of health topics is however increasing.

An active consumer movement is now established in several States. Women's groups and Aboriginal groups have developed their own services with a strong emphasis on health education. Most recently, a new interest in exercise is apparent, as in other developed societies.

In general, the concept of health as a matter of individual responsibility for personal life-style is gaining ground in the more educated. It will be the task of the next 5-10 years to increase this awareness of a health-promoting life-style throughout the whole population. It will then become possible for the social process to become more active in the improvement of health - using legislative and educational means as well as research and innovations in services.

The social process model that has been described in the light of recent Australian developments indicates the importance of the electorate being adequately informed in order to provide the base for mature political decision. In parliamentary democracies, the interplay of opposing forces usually leads to compromise, with resulting incremental change rather than major innovation. This applies particularly to economic issues where employment and investment returns are important; for example, the agricultural brewing industries. The successful introduction of the seat-belt legislation indicates possibilities for social and political decision affecting a large industry. There can be no doubt that major sudden social changes affecting health have been part of revolutions rather than evolution! There is, however, no cause for despair because of the basic ingenuity of man and the fact that ultimately scientific fact becomes dominant in decision-making. So there is room for cautious optimism about the future of health improvement in Australia.

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WORKSHOP DISCUSSION

ECOLOGICAL AND HEALTH CONSEQUENCES OF SCIENCE AND TECHNOLOGY

REPORTER

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It is true that there are large ecological and health impacts of science and technology. However, when we commence to try to examine this impact, it is really quite difficult, for we immediately begin to assess, instead, the ecological and health impact of the development process, of which science and technology is a key, but by no means exclusive, component. Alternatively, we examine life-style changes where science and technology plays a part, which although crucial, is also indirect. Science and technology cannot be easily separated from the social processes of which they are part; nor should they be. The syndicate also had this problem, and found itself examining the development process as the causative agent rather than science and technology.

The general theme of syndicate discussion was: 'The intended and unintended ecological and health consequences of development packages which are exported from developed to developing countries, with special reference to the scientific and technological components of these development packages.' More specifically, the syndicate considered development packages which are funded by both the private and public sector (foreign aid). Thus, the group decided it would:

(1) not make further 'shopping lists' of ecological and health impacts of science and technology. The papers of Drs Millington and Hetzel had already done this to some degree;

(2) not document aspects of this problem in Australia, except in ways which impinged upon the development problems of developing countries, or which were related to the very similar problems faced by Australia's Aboriginal people;

(3) not look further at the life-style-caused impacts which are documented in Dr Hetzel's paper. Ultimately the export of Western life-styles to developing countries could be more catastrophic than the export of any other aspect of development or its component science and technology. However, this issue was too broad to be dealt with in the time available.

The syndicate wanted to concentrate on a more definable and realisable target. It decided that there was not much value in concentrating on the outcome of decision-making, be it a good or bad ecological or health product of development. It would concentrate instead on the development transfer process which created it, and examine ways in which this process could be modified in order to produce a better result in the future.

The crucial part of this process is the delivery of a package of money and knowledge to a developing country or to the aboriginal people of that country. While Australia's development assistance program is becoming well coordinated and managed, the activities of Australians in the private sector are, in our view, proceeding without adequate prior assessment or monitoring.

However, we certainly do not want to be accused of attaching more strings to aid packages just at the time when the proportion of untied aid is increasing. Especially as Australia, by untying its aid to Papua New Guinea, is a significant force in the movement towards the general untying of aid. Nevertheless, the syndicate recognised, through the fairly extensive discussions of both ecologically successful and disastrous development packages, that a much better job could be done. The Ambuklao Dam in the Philippines and the Lungga Dam in the Solomons are two examples of 'disasters' and both have significant foreign aid components. They illustrate the danger of the aid-giving nations, even when aid is untied, being held responsible for the disasters which their aid made possible. Australia must assume responsibility for ensuring that, so far as possible without the tying of aid or interference in the autonomy of the aid-receiving communities, money and knowledge, both in the public sector (foreign aid) and the private sector area, are used wisely, in ecological and health terms.

The syndicate considered, and then described, a theoretically desirable development transfer process which should apply and, to the extent of its collective knowledge, compared this with the existing situation. In its view, the theoretically desirable process should consist of four stages:

- the proposal stage
- the evaluation stage
- the implementation stage
- the review and monitoring stage

At each of these stages there would be many difficulties in developing workable and successful, yet sensitive, integration with the planning processes and systems existing in the developing countries concerned. The syndicate believed that, despite these difficulties, Australia, as an aid-giving nation, had a responsibility to satisfy itself that at each stage appropriate procedures were followed to assess the environmental and technological appropriateness of the proposals. It was recognised that insistence on these procedures being established by the aid-receiving nation might be seen as paternalism. However, the syndicate believed that so long as the judgements involved were the responsibilities of agencies of the aid-receiving nation, this risk could be accepted. It would be possible also to point to the practice of the World Bank which itself carries out such assessments within its own organisation for all projects submitted to it for funding.

The syndicate recognised that many developing countries have very limited human resources available to ensure that both ecological wisdom (including health aspects) and technological appropriateness prevail. In these circumstances it is essential that we should demonstrate to the developing countries concerned, and also to the Australian parliament and public, that we are acting in a responsible manner. The developing countries can check our work, but they can't do it alone and we should not ask them to.

In considering the suggested development transfer process, the syndicate reached a number of firm conclusions.

* The Proposal stage

Australia should devise a set of environmental and health criteria to permit the evaluation of the broad ecological and health implications of all proposals of foreign aid, and of private sector investments overseas. These criteria would advocate a unified human ecological approach to planning, wise resource management and sensitive planning of cultural systems and adaptation, including power relationships. More economic criteria, such as social equity and regional economic development aspects, would also be included. The syndicate strongly felt that these criteria were largely nonquantitative. Unfortunately, a positive cash flow over an agreed period is too often the only criterion used for determining project approval. Frequently even these 'economic' analyses are grossly inadequate.

* The Evaluation stage

Clearly, the evaluation stage is the most crucial of all. Programs should be evaluated with regard to their effect on whole systems and this should include ecological, social and demographic and population aspects. It was considered important that assessment should provide an opportunity for opposition and criticism to be expressed and for a judicial weighing of conflicting views. The syndicate recommended the implementation of existing Australian legislation for large development transfer programs (see recommendations).

* The Implementation stage

The syndicate recognised the importance of 'local input' during both the planning and implementation stages and discussed at great length the need for maximum control of the development process in situ by the affected people. We were of course asked to consider individuals. In passing, the group recognised the impact of the recent Alma Ata conference on primary health care and the need to maximise control at the village (consumer) level. For many developing countries, though certainly not all, and for Australia's Aborigines, increased self-reliance and self-management is the policy aspiration anyway.

It is our view that most ecological and health indices would increase as local self-reliance, and local control and management were maximised. Australia should encourage this where possible by including in its development aid packages employment opportunities for community organisers. They should be drawn from the affected people and belong to them. They should be involved in the planning, implementation, and review and monitoring of development projects. We recognise the political sensitivity of this approach, particularly in some countries with autocratic Governments. However, we believe that only with such decentralisation of power will ecological and health indices really improve in most developing countries.

* The Review stage

Developing countries usually lack the human resources needed to monitor and investigate changes on their environment, on both a long-term and short-term basis. These investigations are essential for the achievement of good environmental management. Developed countries, such as Australia, can assist significantly by helping developing countries where skilled human resources are, usually, very scarce. Such monitoring activities should be component parts of all development package proposals. They could also constitute separate aid programs, without being tied to particular development proposals. Such investigations should include base-line investigations to understand the state of the environment together with the nature and magnitude of processes already changing it, and incremental studies related to understanding the effects of individual development programs.

Because the group concentrated most exclusively on the practical aspects of managing the transfer of development process, it made a series of specific proposals for government action. These could be considered by the Government and, if found acceptable, instituted before the UNCSTD conference in August as part of Australia's preparatory contribution to it.

The proposals are as follows:

1. The Environment Protection (Impact of Proposals) Act should be implemented for all large development transfer programs in both the public and private sector.

There are only two heads of constitutional power where the Commonwealth Government can implement this legislation on the public and private sectors equally. One is on the export and import of materials, such as minerals, and the other is the export and import of money. We feel that it is essential that this be done for significant and large projects. A public review process in Australia, and also in the affected developing country, should be instituted. This is provided for under the Act. The need for an independent tribunal was strongly advocated by some members of the group, in order to ensure a judicial weighing of evidence about costs and benefits. The reports of such a tribunal would provide a sound basis for the democratisation of the planning and evaluation stages.

The ADAB Consultative Committee on Research and Development (CCRD), and possibly a Standing Committee of the Parliament, could be given a crucial review role in the evaluation of proposals, after the more technical aspects had been elucidated in this process. These Committees would be free to concentrate more on the policy/political content of the proposal rather than deal with large amounts of technical data.

2. A small-projects division of ADAB should be created and funded separately.

We all felt that ecological and health goals are often served, and adjustment problems minimised, by encouraging 'smallness'. Such a small-projects division would be one way of achieving this. There are of course other ways, including greater delegation of decision-making power over small projects to Australian diplomats in the developing countries concerned, without referring everything back to 'head office'. The process of funding projects in such a division should be as unbureaucratic as it can possibly be. It could be on a similar line to the innovations program of the Schools Commission. Projects of this division could be exempted from the Environment Protection Act.

3. Australia should provide funds for the setting up of more independent advisory teams along the lines of UNDAT, the UN Development Advisory Team which is based in Suva, Fiji.

The syndicate saw these as immensely useful third party advisory teams. They are quite separate from the interests of donor and recipient countries alike. These teams should be assisted by the secondment to them of Australian experts of all types. UNDAT emphasises sound environmental management and technological appropriateness as a matter of course. Teams such as this, which are funded within the UN system, are also a lot cheaper than commercial consultants.

We have concentrated on the process rather than the product. If we in Australia simply set up vigorous processes and ensure that they are implemented thoroughly before approval is given to programs, we are likely to avoid ruffling the feathers of developing countries. However, they will no doubt be very angry if we talk about vetoing the development package itself. While we should see to it that every stage of our process is gone through carefully, once the decision is made we should live with it. In this way, we will probably ensure a greater proportion of successes to failures, in the ecological and health sense. If disasters do occur, it will be because decisions are being made by people in recipient developing countries to go ahead anyway. Then, at least, it will be their fault and not ours.

The UNCSTD Conference emphasises science and technology as an engine inside the development process. This concept is somewhat strange to many people in the developed world. Yet it makes very great sense. With the notable exception of the rural sector, there has, in practice in Australia, been a large gap between, on the one hand, the creative processes of science and the innovation of technology, and on the other, the development process itself. Developing countries are anxious to ensure that this does not happen to them. In our relationship with developing countries we should ensure that we do not undermine their aspiration by either accident or design.

THEME 3

APPROPRIATE EDUCATION AND TRAINING IN SCIENCE AND TECHNOLOGY FOR SPECIALISTS; APPROPRIATE EDUCATION TO ALLOW EFFECTIVE EVALUATION OF SCIENCE AND TECHNOLOGY BY ALL GROUPS IN SOCIETY, ESPECIALLY DECISION-MAKERS (PARTICULAR EMPHASIS ON WHAT SCIENCE CAN AND CANNOT DO)

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INTRODUCTION

Professor Jevons examines the basic prerequisites for the smooth integration of science and technology with social objectives. He challenges the assumption of technological determinism - that social choices are predetermined by technology. Imperfect understanding and development of the patterns of interaction between experts and laymen are identified as crucial problems. Professor Jevons takes illustrations from two papers prepared for the United Nations Conference on Science and Technology for Development, the Australian National Paper and the South Pacific Sub-Regional Paper, to show that the educational and manpower implications of both are in broad terms similar and indicate a need for greater efforts to see technical factors in wider contexts. The role of educational programs setting out to deal explicitly with the interactions between science, technology and society is assessed. Professor Jevons suggests that we should work towards a 'civilised science' which is fully within the arena of public debate.

Mr Morgan presents the view that science and technology are most likely to contribute significantly to social and material change when a society has not only a number of scientific and technological innovators, but also an informed citizenry able and willing to apply such knowledge and approaches to meeting their own and society's perceived needs. They are unlikely to do this unless they have had appropriate, rewarding experiences of science and technology themselves.

In societies which provide universal schooling, the schools seem the logical place to undertake the basic scientific education of the community. However, systemic features of educational systems, students' immaturity and the ways in which science is taught commonly result in science teaching achieving less than might be hoped for it. Recent efforts to assist school science teaching by producing classroom teaching materials do not fully overcome such limitations. These considerations lead to some important questions.

Professor Whitton's paper is divided into three main sections. First, the development of technical training in Australia since the early settlement days of the late 1700s is traced against a background of similar world development, leading on to training in the sophisticated technology of the 1970s. The early establishment of the mechanics institutes, schools of mines, technical colleges and universities is related to the period of scientific and technological invention throughout the world. From the middle of the twentieth century the historical survey is more detailed and leads on to the second part of the paper, a critical examination of what was attempted in technological education and the result. This has the object of learning where mistakes may have been made or where omissions occurred.

THEME 3 - Introduction

In the last section Professor Whitton discusses what is needed in approach, training and attitudes to prepare Australians for the future in technology and its applications. This covers both specialised technological fields and the requirements for technological knowledge of all people, particularly future managers and decision-makers.

Professor Whitton discusses a number of social issues which relate to the ways in which technology has been applied. The end point of this centres upon the problems of inflation, unemployment and the displacement of people by machines and systems in the current age.

The discussions evolved a general approach which was favoured for cooperative educational and training ventures with developing countries. The syndicate examined education through organisations - schools and post-secondary institutions and for continuing and further education. It also looked at ways of informing decision-makers and the general public on scientific and technological matters.

A specific proposal was made for a National Program of Public Information on Science and Technology. Features of the program would include a National Science Centre, better scientific and technological material in public libraries, provision of suitable material for the media, and encouragement of training in communications skills for professional scientists and technologists.

SCIENCE FOR THE PEOPLE:
AN OLD DREAM RE-DREAMT

BY

F.R JEVONS

Professor Jevons, MA, PhD, DSc, obtained his PhD in biochemistry in 1953 from Cambridge. He held various appointments in biochemistry at the Universities of Washington (Seattle), Cambridge and Manchester, and in 1966 was appointed first Professor of Liberal Studies in Science at Manchester University. The interests of the department developed by Professor Jevons centred upon an examination of science from the economic, social, historical and philosophical standpoints. In 1975, Professor Jevons was appointed foundation Vice-Chancellor of Deakin University at Geelong in Victoria. He has written four books and contributed to three more.

BERNAL'S VISION

The vision of science serving the people was never expressed more forcibly than by J.D. Bernal. 'The world is going scientific, and the sooner people see this and act on it the better' he wrote.[1] He envisaged a society permeated through and through with science.

> '...On the long-term view we must look forward to a fairly rapid transformation in which scientific functions - not necessarily scientific research and development only, but scientific production and scientific administration - will absorb a progressively larger and larger proportion of the population. From one-tenth of 1 per cent we may advance to involving one, two and possibly ultimately, but in the far distant future, as much as 20 per cent of the population in such activities.'[2]

Now, in 1979, that vision repels more than it attracts. It seems like overweening scientism - the extension of the methods and attitudes of science into areas where it is not appropriate. For most people nowadays such technocratic fantasies are nightmares, not utopian dreams.

But people in general *can* choose where science and technology are to take the societies in which they live. To regard science and technology as servants of society, created not to command but to obey, is a more humane and civilised vision. It has elements of fantasy about it but it has been realised in part and can be realised more fully in future.

That then is how I want to redream Bernal's dream: not scientism run amok but science smoothly integrated with social objectives - not science *by* the people but science *for* the people.

In this paper I examine the basic prerequisites for achieving Bernal's dream in its modified form. First, I lay the ghost of technological determinism, which can cripple discussion of technology-society interactions if allowed to go unchallenged. After identifying the relationships between experts and laymen as a crucial problem, I scrutinise papers on two contrasting regions - Australia and the South Pacific - for clues as to how the problem is perceived there. The unifying feature is the need to see technical factors in wider contexts, and I examine educational innovations designed to help meet this need, with an emphasis on courses designed to be accessible to non-specialists.

THE DUAL DETERMINATION OF TECHNOLOGY

It is necessary first to lay the ghost of the idea that the development of society has to follow a path predetermined for it by technology. This kind of technological determinism suggests that technology has the effect of closing our options. It is implied by the often repeated suggestion that technology is out of control, like a wild horse that is running away with us.

This notion cannot stand up to serious scrutiny. Far from closing options, technology expands the range of choice open to us.

The one thing that is inevitable about technology is that we must have technology of some kind. Technology is inescapably a constitutive part of society. Romanticists may construct idylls about a return to some imagined state of nature in the past where paradisiac perfection reigns, but this is little more than a form of release for the personal frustrations of middle class minorities. In practice, on a large scale, it could lead only to disaster. It is a theoretical and a historical possibility only, not a real option. We could have low technology, but we can't have no technology. I am tempted to adapt Henry Ford's dictum about customer choice of colour in cars. Ford said, about that particular case, 'you can have any colour you like as long as it is black'. I want to say, about technology in general, 'you can go in any direction you like as long as it is not back'.

The *kind* of technology we have is not inevitable. The sense of inevitability which many people have is described and then undermined by Rose and Rose.[3] There is a common impression, they say, that 'nuclear fission and hence the bomb were inevitable, molecular biology and hence genetic engineering, information science and hence computers and artificial intelligence are inevitable, battery chickens are inevitable, going to the moon and the motor car are inevitable. ...' In fact, however, the kind of science and technology we have is 'the product of certain philosophies, ideologies, economic and political structures'. We can choose the science and technology in the same kind of way as we can choose our philosophies, our ideologies and our economic and political structures.

Such choices are not free and unconstrained. Inertia is powerful, disagreements stark, vested interests deep, and political mechanisms imperfect. Ultimately, however, the technological options we adopt reflect social choices and priorities. In the last analysis, there is no such thing as a technological imperative. Every piece of technology that is introduced is the choice of some sector of society, however small the sector and however ill considered the choice.

A few years ago, I found myself debating the same issue from just the opposite starting point.[4] Some writers adopt an extreme social determinist view and argue that technology is completely determined by social and political factors. Thus, Melman says that each machine has built into it 'the particular requirement of whoever decides its characteristics and the uses it must serve'. He calls it a 'distortion of understanding' to make technology 'appear as though independent of man's will'.[5] I felt it necessary to point out some necessary qualifications to Melman's view. The characteristics of a machine are only in part determined by the user specifications; some characteristics are the way they are whether the user wants them that way or not. The properties of substances and forms of energy are matters which are 'given' and we must accept them. We can try to understand and exploit them, and the better we understand them the more ingeniously we can exploit them, but we cannot change them. Thus the social determinist view of technology is no more than a half truth.

A serious deficiency of the social determinist view of technology is that it does not allow for the capabilities which, though latent, are nevertheless inherent in technology. The range of such capabilities goes beyond those actually in use at any particular period in history. As an example, let me take the telephone system. Dickson, attacking 'the myth of the political neutrality of technology' in a way reminiscent of Melman's argument, cites the telephone system as we have it as a reflection of the 'individualistic' nature of our society because it is designed for communication between two individuals rather than for group discussion.[6] But to adapt the system for group use is easy: the technology is almost identical. The way we use the technology is of course determined by social preferences, but the range of capabilities for which the technology can be adapted or developed is much wider.

I have gone into this debate and mentioned the opposite extreme position to give emphasis to a point which is central to my theme. Our choices, while on the one hand dependent on technological possibilities and to that extent technologically determined, are on the other hand also subject to social determination. This dual determination sounds simple in theory, but in practice it is anything but simple because the social mechanisms are complex, imperfectly understood and imperfectly developed.

EXPERTS AND LAYMEN

Difficulties arise because of the esoteric nature of technology. Most people don't know much about any kind of technology and nobody knows much about most of it. We cannot, therefore, resort to easy populism, however heady the talk about mass participation in decision-making. The limitations of participatory democracy are especially acute in areas which call on relatively esoteric knowledge, such as technological expertise. One form of equality to which I cannot subscribe is equality of weight of opinion. It would be foolish and absurd to weigh all opinions equally. Informed opinions are worth more than uninformed ones.

But we must beware also of going to the other extreme. Experts are a mixed blessing. They are rarely free of vested interests, not usually financial ones but sociological and intellectual ones. Too often they have tunnel vision rather than a panoramic outlook. A French Prime Minister is reported to have said that there are three common ways for man to ruin his career: chasing women, gambling and trusting experts. Of these, he said, chasing women is the most pleasant, and gambling is the quickest, but trusting experts is the most certain.

The crux of the problem, then, is the pattern of interactions between experts and laymen - laymen in this context being taken to include experts in areas other than science and technology.

The attractions of the 'leave it to the experts' view are easy to see. Every expert has the elements of a layman in him, but laymen are commonly so daunted by the apparent inscrutability of expertise that they don't even try to understand the issues involved. The idea that decisions involving technology should be left to experts therefore commends itself easily both to experts and to laymen. The case for enlightened elitism seems strong. Indeed, to question it is sometimes interpreted as casting doubt on the integrity of the elite; to suggest that laymen should also be involved is taken as tantamount to accusing the experts of bad faith towards the rest of society.

TWO UNCSTD PAPERS COMPARED

In fact, however, it is not necessary to cast any doubt on the integrity and good faith of the experts. The case for wider involvement in the decisions rests on other grounds. To illustrate this in a way relevant to the present context, I will pick a few points from two contrasting papers written for the United Nations Conference on Science and Technology for Development, the Australian National Paper and the South Pacific Sub-Regional Paper, to see how the problems are perceived in two very different areas.

A recurring theme of the Australian paper is that the availability of the requisite technology is a necessary but not a sufficient condition for its implementation. Thus, the Australian paper identifies inexperience and conservatism among managers as an obstacle to better utilisation of science and technology. The conservatism is attributed to the inexperience: 'managements often lack the experience to appreciate the possibilities of science and technology'.[7]

In the South Pacific there is a severe shortage of scientists and technologists themselves. There are only three per 10 000 of the population, and of those 80 per cent are not of local origin and therefore suspected of lacking appreciation of, and sympathy with, local culture. This is seen as a danger because the South Pacific paper insists that development should be 'on our terms'.[8] The fear is expressed that technology will continue to be carelessly imported, with undesirable effects on foreign exchange, environment, employment, skill creation and so on. Local scientific and technological resources should be devoted largely to improving the capacity to evaluate and bargain effectively for foreign technology. This, according to the authors of the South Pacific paper, is the best way to maximise the net benefits to the existing cultures of the region.

Resistance to technological innovation on cultural grounds can be strong in South Pacific islanders.

> 'Well-meaning technical advisers have often been frustrated in their plans for technological change by what they saw as 'half-hearted' cooperation by local people. Indeed some of these advisers have erroneously believed that the reason for failure of projects has been the fault of the 'islanders' and statements like the following are often heard:

> 'Islanders are so unready for development that they inevitably fail to put oil in gear boxes and wreck valuable machinery...'

But the 'gear box syndrome' should not be misdiagnosed. It is often interpreted as sheer incompetence, but it may in fact be a way for local people to demonstrate 'in the polite Pacific manner that the imposed development does not fit in with their local cultural standards'.

Resistance to innovation is not confined to non-western countries. The Australian paper documents lengthy resistance to the introduction of objective measurement of wool. Externally induced crises were necessary before the innovations were accepted. Nor is the resistance always due only to sheer stubborn conservatism. 'On the contrary' says the Australian paper in one connection - agricultural extension work - 'it may well have been the result of the producer's eminently practical judgment' Whereas agricultural extension workers provided advice on specialist aspects, the producer himself was better placed to view the operation of the farm as a whole. Now that the deficiency has been recognised, whole-farm extension work is becoming more common. It is suggested that the lesson learned should not be confined to the agricultural sector and that manufacturing could benefit too, despite the very different structure of industry in that sector.

As for the institutional forms guiding the utilisation of science and technology, there are implications that the Australian system is over-bureaucratised. The Australian paper refers to 'proliferation of government instrumentalities concerned with science and technology'. The South Pacific paper suggests a more populist approach. The authors believe that technical advisers have not always taken enough care to communicate with all those likely to be affected by changes. In preparing their own paper, they undertook an extensive series of visits to Pacific islands.

Despite the marked contrast between the detailed circumstances in Australia and the South Pacific, the educational and manpower implications of the two papers are, in broad terms, similar. The Australian call for a higher level of technological awareness among managers is basically similar to the South Pacific judgment that scientific and technological expertise is needed more for evaluation and bargaining than for research. The trend in agricultural extension services shows some parallels to the call for technical advisers in the South Pacific to be more widely sympathetic to the whole set of local economic, social and cultural factors.

The unifying feature is the need for greater efforts to see technical factors in wider contexts. That is the general implication of the Australian theme, that the availability of the requisite technology is a necessary but not a sufficient condition. It is not mere receptivity to science and technology, not mere enthusiasm for innovation, that is wanted, but the ability to discriminate and choose what kind of technology to use, bearing in mind not only the immediate effects but also the probable more remote consequences.

WHAT CAN REASONABLY BE EXPECTED OF EDUCATION

We must be becomingly modest about the role of education in tackling the social problems surrounding the use of technology. Education is not a panacea for social ills. We do well to remain suspicious of attempts to use education as a direct tool to engineer social change, and in any case we have to retain due scepticism about the capacity of education to act in this way. Nevertheless, there are ways in which the education system can respond to perceived social needs.

The general conclusion that technical factors need to be seen in wider contexts means that different kinds of expertise need to be mixed. Such mixing can be achieved by bringing together experts of different kinds. Some experts, however, remain so locked within their areas of expertise that they find it difficult to interact constructively with experts of other kinds. They may even lack the degree of sympathetic understanding which would make them want to try. They may therefore separate out into groups with like inclinations, like oil separates from water.

It is useful, therefore, to have individuals who can act as 'detergents', with affinities for both the oil and water phases - individuals, that is, who combine within themselves a mixture of skills. Such mixtures within individuals can arise in a number of ways. There is some mixing of different subjects within educational programs, though at university level there is not as much as in my view there should be. Many scientists and technologists acquire skills in other areas by professional experience or further study or just as a matter of general interest. The reverse, though, is less common. It is relatively rare at post-secondary level for people not trained in science or technology to embark on serious study in those areas; the road seems too long and the early stages too remote from practical problems.

I want to mention here some attempts to tackle the problem in a somewhat different way, by setting out to deal explicitly with the interactions between science, technology and society. Some scholars are sceptical of such attempts; scientists tend to believe at first that they are a waste of time and that students would use their time better by just learning some science. I believe this to be too short-sighted and narrow-minded a view. Science, technology and society courses can usefully broaden horizons and expand the range of skills of science and technology students, but there is another and even more important application: such courses can be made accessible to a wider public. A high level of scientific or technological expertise is not a necessary prerequisite; although more can be done with those who have some science and technology background, much is possible even without this.

We must not expect too much, too quickly, from such educational initiatives. There are no quick and easy solutions - any more than faculties of commerce can provide quick and easy solutions to the problems of the business world. What one can reasonably expect is a generalised rather than a specific relevance: conceptual tools for handling the problems, a pool of people who have thought about them, and a more than superficial understanding of past situations to immunise us against the worst naiveties we could fall prey to.

SCIENCE, TECHNOLOGY AND SOCIETY COURSES

Courses of the science, technology and society type have sprung up in various institutional contexts; there is not yet a received body of doctrine such as would merit the description 'discipline' and in different institutions there are varying emphases as between undergraduate, postgraduate and research work, between economic, social, political, philosophical and historical approaches, and so on.

I was fortunate enough to be associated with one of the earliest programs, Liberal Studies in Science at Manchester,[9] which was founded in 1966. Others in Britain include those at the universities of Sussex, Edinburgh and Aston. In Canada the founding in 1968 of the Science and Human Affairs program at Concordia University, Montreal, was among the earliest major ventures designed specifically for arts students. Dozens of programs have been founded in the United States of America and there is testimony to the continuing vitality of the movement in the fact that three foundations in 1978 contributed $2.5million in start-up funds for a new program at Massachusetts Institute of Technology.

The institutional development of the field in Australia has been reviewed by Ronayne,[10] who mentions undergraduate teaching at seven universities (Deakin, Griffith, Melbourne, Murdoch, New South Wales, Sydney and Wollongong) and two colleges of advanced education (New South Wales Institute of Technology and Swinburne College of Technology). His list is not exhaustive and other institutions are also active in the field - for instance, the Western Australian Institute of Technology - but the length of the list could nevertheless be deceptive because the scale of effort is really quite small. Only two universities, New South Wales and Griffith, have research centres, and they are described by Ronayne as 'embryonic'.

For no better reason than the fact that I know it best, I will give a brief description of the activity of my own university in this field. At Deakin University there is on offer for the first time in 1979 a course called Knowledge and Power. The title Knowledge and Power carries a deliberate double meaning: the intention is to explore interactions between knowledge on the one hand and on the other hand both power over the physical universe and the distribution of power in human societies. The course is offered by the School of Humanities and has been developed by a small team chaired by Dr Wade Chambers. The social, philosophical and economic analysis of science is illustrated by various case studies. One such case study is on the pesticide controversy and examines how different scientists in different institutional contexts contributed to this particular debate. The implications for the ideal of objectivity in science are taken up during the philosophical analysis. Another case study concerns science in China, where the markedly different perceptions of the role of experts during the rule of the 'Gang of Four' form a striking contrast to western practices.

CIVILISED SCIENCE

Ronayne[10] notes that in the early days science, technology and society courses had a technocratic flavour, whereas later they have come to adopt a more critical orientation, with greater attention to the disillusionment with science and concern over the adverse effects of technology. At the risk of appearing fanciful I would like to suggest that we might see a dialectical process at work here. The thesis is a technocratic one: science is intrinsically a good thing and science students should be given a broader education to enable them to become more effective as scientists. The antithesis is critical: many effects of technology are undesirable and the scientific and technological enterprise needs to be brought under control. The synthesis, towards which we perhaps ought to work, is that science and technology are not intrinsically either good or bad, but the willing servants of society.

If that synthesis could be effectively achieved we would have, in a literal sense, a 'civilised science', a fully integral part of 'civic' organisation and processes.

The notion of 'civilised science' does not amount to the simplistic suggestion that there would be unanimity about matters concerning science and technology. Quite on the contrary, it means that science would be more effectively brought within the arena of public debate, rather than acting as some exogenous factor impinging from outside, as it were, on the system in which social choices are made and priorities determined. To achieve this it is not enough for scientists and technologists to be sensitive to factors outside science and technology. It is necessary also for people outside the scientific and technological community to take part in informed debate, so that other norms and goals and values can be brought to bear and other kinds of expertise utilised in determining directions of development and patterns of adoption.

The ultimate ideal, perhaps, would be for science and technology to become not forces in their own right but willing and versatile servants, applying no constraints of their own but acting merely as instruments necessary to implement decisions taken by the decision-making processes of society at large. It is not surprising if scientists and technologists find this ideal difficult to accept, or if sociologists doubt whether it could ever be fully achieved. In any case, there is no sign of science and technology becoming as completely tamed or as infinitely versatile as the ideal requires. Because the range of technological capabilities we have 'in stock' is restricted, social choices in the real world have to be constrained by what is technologically feasible. Like other kinds of politics, the politics of technology is the art of the possible, and because of the nature of the possibilities, expert-layman interactions are an important part of the art.

Although most of the decisions will in practice be made in bureaucratic structures and committees, they should be made against a background of wide public discussion. That can only be achieved if there is ample exposure of the issues in the media, including the mass media, which to a large extent set the agenda for public debate.[11] The contribution of the educational system is bound to be restricted unless it can present the issues through channels which are accessible to those who are not specialists in science or technology.

CONCLUSION

The direct contributions of education to solving the problems of using science and technology are necessarily small but in the longer term the effects of education may be profound. Since science and technology are inescapable and constitutive elements of society, it is worthwhile to demystify them, so that many who are not practitioners can nevertheless take part in shaping them and thus, in turn, the part they play in shaping society. This does not mean succumbing to facile populist talk of mass participation in decision-making. It does mean that decisions concerning science and technology should be shaped by informed public debate. That debate, as with other public policy decisions, will in practice be confined to a minority, but that minority should be a substantial one, going well beyond the community of professional scientists and technologists. In part it will be institutionalised in agencies and committees, but in part it will also take place in public media, such as newspapers.

The better informed the contributors to the debate, the wiser the outcome is likely to be. In that modified form, Bernal's vision is, I think, achievable and well worth working for.

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SCIENCE EDUCATION IN AUSTRALIA: HAVE SCHOOLS A ROLE?

BY

D.G. MORGAN

Mr D.G. Morgan was formerly Head of the Biology Department, Melbourne State College. He has been active in the design of school science curricula and was a public examiner for many years in Victoria, at several levels in the school system. Since the mid 1960s he has been Supervising Editor of the Academy of Science's school biology materials, Biological Science: the Web of Life.

INTRODUCTION

It is the task of this paper to look at the role of science education in Australian schools as a possible factor in the nation's scientific and technological development.

Because the field is potentially a large one, the aim of this short paper will be restricted to setting out some of what we currently know about school science education, and what seem to be some of the key issues and implications for scientific and technological education in the future, not only in Australia but in other countries as well. It reflects a particular viewpoint developed through many years of involvement in the development of secondary school science curricula and materials.

SCIENCE, TECHNOLOGY AND DEVELOPMENT

In a paper concerning itself with the role of education in scientific and technological development there is a need, first, to clarify what we mean by such terms, then to ask what kind(s) of education are likely to serve those purposes best.

The word 'development', when applied to human cultures, will be taken as having two qualitatively different meanings.

First, development can mean producing changes in a society with the intention that virtually all its members have a set of basic needs met, so that survival to an advanced age, after a rich and satisfying life, is possible. This means being assured of such things as suitable foods in sufficient quantities, good health, shelter, warmth and security, a satisfying understanding of the world, a capacity to cope with everyday problems, rewarding social interactions and recreation.

Secondly, it can also mean going beyond those basic needs to make possible other non-basic things which members of a society at a particular time see either as desirable or necessary. The cars, colour television, air-conditioning and other prerequisites of so-called 'developed' societies are examples. Such societies tend to have mechanized agriculture, fisheries and forestry, mining of raw materials, food processing and packaging, the manufacturing, packaging and marketing of consumer goods, sophisticated medical technology, elaborate housing, transport and communications, energy, water and sewerage systems, defence establishments, entertainments and tourism, extensive education systems, and research, publication and library facilities as well.

If we see science as a process of inquiry leading to a rationally derived, tested body of understanding based on evidence, and technology as the application of knowledge and ingenuity to specific practical situations, then the history of both science and technology shows that both, individually and in concert, have helped provide some of man's basic needs and contributed greatly to providing other perceived needs wherever the necessary material and human resources have existed and people have felt disposed to profit from them.

If scientific and technological development means the production of social and material changes in human societies by applying the approaches, understandings and tools of science and technology to try to meet what are seen as important human needs, then what human resources are needed for a people to profit from science and technology? What is required for people to be disposed to use them? Can the school system help? And, if so, how can one ensure that it plays the role expected of it?

What Human Resources are Needed?

There are very great differences between different human societies in the levels of scientific research and technological innovation. Levels appear to be highest at present in places like North America, Europe, Japan and Australia, which have or have had recently high per capita incomes, moderate population densities, high levels of education and a cultural ethos which values and rewards such activities both by citizens and corporate bodies.

Yet even in these societies very few people are the innovators; most, even amongst the scientific and technological community, and certainly amongst the wider community, seem to be users of innovation rather than innovators themselves. The proportion of the population who have added significantly to mankind's corpus of knowledge or made significant technological advances is very small.

Further, present communication facilities mean that new knowledge can be disseminated rapidly around the world once it has been developed, particularly if its benefits are clearly discernible. The rapid spread of microprocessor technology within some countries in recent years illustrates this.

It may not, therefore, be necessary for a society to produce many people capable of working at the frontiers of science and technology. A more important goal may be to produce a community capable of applying knowledge, developed in the first place largely by others, to the problems of its own local situation. If, as may be the case, present scientific and technological knowledge is sufficient to provide the basic human needs of all the world's people, what is needed to achieve this may not be more people at the frontiers of science and technology, but more people with some understanding of the contributions that science and technology can make towards meeting specific local needs, and the disposition and capacity to recognize what is relevant and apply it effectively.

Choices

In nearly all societies, the actions of the individual member play an important part in meeting his or her own needs and those of immediate dependants. If different ways of doing things are available, then choices can be made. Given an everyday problem, what would make someone seek out and use a scientific or technological solution over some other kind of solution?

Research in the behavioural sciences suggests that a number of factors affect the choices people make in a given set of circumstances.

Knowledge of possible options is one factor; a scientific or technological solution is unlikely to be sought unless the individual concerned knows that a scientific and/or technological solution may exist. Such knowledge must be acquired in some way.

Past experience is another factor. A particular approach is likely to be used again if it has already been learnt and used effectively. Scientific and technological approaches are likely to be chosen only where an individual has learnt what they are and how to go about them, and has learnt from experience to value them. Implementing them is then seen as inherently worth while and potentially rewarding.

The beliefs of the individual also play a role, and beliefs, like other ideas, are based on an individual's past experiences. Particular approaches to a problem are likely to be followed if they seem consistent with the problem-solver's currently held beliefs.

Novelty is another factor. Given two possible approaches, equally attractive when judged by other criteria, the more novel and 'interesting' one is more likely to be tried first. New ideas and new gadgets meet a ready market in many societies.

For some people, particularly those less confident of their own ability to make right choices, the perceived views of others around them are of paramount importance in decision-making. A scientific or technological approach may be chosen only when esteemed associates are seen to prefer it, or when the individual believes he or she will gain kudos by choosing it.

In some situations, constraints imposed by the situation itself may influence the choice of approach. Finally, the individual's own ability to evaluate possible alternatives may determine the final choice.

Once a particular approach has been chosen, it is likely to be continued with only if it proves rewarding, or some form of social pressure to use it continues, or if the individual thinks there is little alternative.

Science and technology are therefore likely to make significant contributions to development only when those who make the decisions in a society have sufficient scientific and technological knowledge, and value scientific and technological approaches more highly than other approaches to a problem, when using such approaches is seen by those individuals as socially acceptable, or the only possible approach in the circumstances, and where using science and technology is seen as potentially rewarding in the long term.

If science and technology are to contribute to development, then, the decision-makers of a society require appropriate experiences at some stage in their lives from which they can learn, and these must prove rewarding to those individuals. They may, too, need to gain confidence in their ability to solve problems in these ways in order to prefer such approaches to others.

Decision-Makers

A society may be able to manage with a relatively small proportion of scientific and technological innovators. But for the society as a whole to profit fully from science and technology, the ordinary citizen, very often the real decision-maker, has to recognize that there is a place for scientific and technological solutions to everyday problems, and may need to acquire the capacity to apply such knowledge to his or her own situation. If science and technology are important, then measures may have to be taken to ensure that the ordinary citizen develops both the necessary knowledge and capabilities. Making such opportunities available may be a role for the education system.

Learning to use science and technology in the 'real world' may be easy, or it may be difficult. Today the citizen of a developed society can watch events on the other side of the world, using personal technological capabilities no more sophisticated than being able to switch the television set to a particular channel. But to be able to vary a farming method so that the highest possible yield is gained from a crop in a variable climate, or to be able to evaluate and vote wisely on some local resource management policy, may call on considerable knowledge, an ability to apply that knowledge in a rational way, and a disposition to do so.

A disposition and ability to apply scientific knowledge to everyday situations in rational ways is by no means a cultural norm. In countries like Papua New Guinea, the existing cultural ethcs may predispose other approaches. Even in Australia the prevalence of other problem-solving strategies where scientific ones are likely to be the more rewarding suggests that, for many, the scientific education they have had has not been effective.

How, then, can a nation provide a suitable system of scientific education: one which will produce a few career scientists, a few people who will become community leaders and make decisions which take into account scientific and technological solutions to community problems, and a large number of ordinary people able and willing to apply scientific solutions to day-to-day problems whenever such solutions are likely to be relevant? The formal systems of education universal in 'developed' societies appear to offer a possible avenue.

Many societies have sought to provide opportunities for their citizens to gain scientific or technological education through the formal structures of their education systems by making available primary, secondary, tertiary and further education programs for at least a few of their citizens. Few societies make such courses mandatory, and, even if they are mandatory, the goal often set is not performance in life, but some readily assessable short-term goal, like a passing mark in an examination stressing recalled verbal information. The skills required to do this may not be those which lead to the application of scientific and technological approaches in their own lives. It may be important, therefore, to ensure not only that appropriate education is provided, but that it is given to at least a high proportion of society's decision-makers, and is effective.

SCHOOL SCIENCE EDUCATION

(The remainder of this paper will look primarily at the scientific side of education for development; technological aspects will be left to other contributors. The focus will be on formal schooling as a possible agent for such change.)

What sort of scientific education is needed for development? And at what stage in people's lives? Is formal schooling the right way to effect it and, if so, at what grade level(s)? Who should decide what is done? Who should teach it? How should the teachers be trained? And how can one ensure that the scientific education received by a student is adequate?

Aims

In recent years a fairly clear consensus has emerged as to the goals which should be pursued in school science education. Since the early 1960s there has been fairly general agreement amongst science educators - those who determine the content and approaches of school courses either through syllabus and examinations or through teaching materials production - that a scientific education should foster in the student:

- a scientific understanding of a natural world;
- an understanding of the nature of scientific knowledge, including both its benefits and limitations; and
- some ability and disposition to apply scientific knowledge and problem-solving approaches to problem situations.

Choices must of course be made to decide what parts of mankind's body of scientific knowledge should be included in a course of study. The most common bases for selection (or rejection) have been the immediate or potential applicability of that knowledge to the student (now and in future) and, where relevant, its perceived importance as a basis for later study.

Timing

Studies of intellectual development in children suggest that what students are capable of learning at a particular age depends on inherited factors, the kinds of experiences they have had in the past, the types of learning situation available and the maturity of the student.

It seems that some of the information derived from scientific work can be acquired by children at quite an early age. But most children, in Western societies at least, do not begin to develop significant reasoning capacities until of primary school age. And the ability to use hypothetic-deductive reasoning, an important part of scientific work, does not seem to develop in most students until well into their secondary schooling, or even later. Many people seem to show no evidence of such reasoning at any stage in their lives.

There is evidence, too, that ways of thinking are, in part, an outcome of appropriate learning experiences. So student achievement of the aims of an educational program will depend partly on the nature of the aim, partly on the kinds of learning opportunities available and partly on the age and background of the student.

So the more intellectually mature the student and the better the educational opportunities available, the more likely he or she will be to acquire a capacity for scientific decision-making. So the best time for such an education seems to be at as late a time in formal education as possible, perhaps during tertiary education (though the building up of a range of background experience and skills can begin as early in formal education as the opportunity offers).

Running counter to this line of reasoning is the acceptance by most societies that universal education is best given only at primary school level, at a time well before the 'optimum period' for scientific education. In many societies only an elite few will have even the possibility of acquiring, during their formal education, the scientific education desirable for national development.

The best compromise may be to try to offer a worthwhile science education as late in formal schooling as a society permits.

Teaching Methods

It seems that, although many individuals seem capable of attaining relevant capacities, at least to some extent, they may need appropriately taught senior secondary science programs if they are to achieve it. Unfortunately some ways of teaching do not appear to foster students' reasoning abilities; and those methods may predominate in a child's schooling.

Whether or not the student is disposed to seek scientific solutions to problems depends to a considerable extent on whether or not he or she has tackled problems in this way during the educational process, and on whether doing so has proved rewarding. Rewards can come from personally satisfying problem-solving experiences, from teacher and peer approval of the attempt, and from formal tests which have reinforced such approaches. All affect the likelihood that such approaches will be used again in the future. Many teachers place little or no emphasis on problem-solving in their science courses.

And well-meaning attempts can fail. For instance, too early an experience of too difficult a problem can make the student less likely to try scientific approaches in future.

So abilities to apply both scientific knowledge and scientific problem-solving approaches seem to depend partly on what the student has learnt - and on the kind of teaching he has had - and partly on maturity level and genetic factors. Although a gradually increasing ability to achieve this goal can reasonably be expected in most students as age increases, achieving it may depend on receiving particular kinds of teaching.

A ROLE FOR SCHOOLS

The period of secondary schooling, when many students currently receive their entire science education, appears to offer a possible time for the general scientific education of the citizen and the basic training of the future scientist and technologist going on to further education. Whether or not the experience achieves its aims, at least to some extent, may depend on enough time being found for it, it being given at a stage in schooling when it is most likely to be effective and on appropriate teaching methods being used.

The Past Situation in Australia

It is probably true that in the past Australian society has had only a small proportion of scientific and technological innovators. Those people appear to have come largely from the relatively insignificant proportion of the community able to provide its students with a full secondary school education, often with tertiary education to follow. For many, an interest in the applications of science in the real world was kindled by an enthusiastic teacher dedicated to his subject and its teaching.

The possibility exists, too, that those who taught such students were also, in general, better qualified as a group than the average secondary teacher in the vastly expanded secondary school system for the present day.

For, from the end of World War II until the mid-1970s, a very great expansion took place in Australian secondary education, with great increases in the number of secondary schools, students and teachers. Now virtually all Australians remain at school until the ninth or tenth year of schooling, after which the proportion at school declines.

Barriers to the student remaining at school until Year 12, if desired, have gradually been removed. In the period mentioned, considerable sums of money were spent on science laboratories and equipment.

Yet the flood of new teachers of science, as one part of this expanding system, often had relatively little education themselves in the application of science and technology to problem-solving, let alone the capacity to teach it.

The Current Situation

Science is only a part - and often not a very great part - of Australian schooling.

Primary Science : Some workers believe that the time of primary education is a period in which the child is capable of acquiring, as well as basic skills, a wide range of experiential knowledge. Such knowledge can serve as a basis for a developing understanding of the world, and be developed in such a way that the young child's tendency to actively explore his surroundings is not lost. In past years 'nature study' played such a role in the hands of the interested teacher.

The more recent advent of 'science' as a content option for the primary school appears to have been accompanied by a decline in the amount of scientific knowledge taught. In Australian primary schools relatively little time is now devoted to any form of science education. It seems that a high proportion of primary teachers are, for various reasons, antagonistic to science work in primary grades. Only in a couple of Australian educational systems is there any strong pressure on teachers to find some time for primary science. Consequently, if the teacher is to be relied on to find more time for it, and develop a suitable program, we might expect very little science teaching in the primary school in the future.

Junior Secondary Science : The first few years of secondary school, as the end of the period when all Australians are still at school, is the last opportunity for a worthwhile basic science education for many future citizens. Virtually all Australian secondary schools offer some kind of general science program to a majority of their students, sometimes to all. But the time given to it may be as little as one and a half hours a week.

And what is taught to students in that time is left largely or entirely to the discretion of the teacher. What the teacher covers is laid down by educational administrators in only a few of the Australian school systems. Left to himself or herself, the material the teacher includes is much influenced by his or her own past experiences. The methods of teaching used are left entirely to the teacher and depend, in turn, on the kinds of pre-service and in-service teacher education available.

Unfortunately the age of the student at the time of junior secondary schooling seems to be too low for most students to become adept at rational, empirical problem-solving. The concerns of adolescence, combined with the ways in which many schools and school systems operate, make it potentially difficult for even the best educated and most capable teacher to provide a worthwhile science course at junior secondary level, the kind of course likely to have a lifelong impact on the student. (Such difficulties are not, of course, confined to this country.)

Senior Secondary Science : Only in two Australian States do a majority of students remain at school beyond Year 10, and less than a quarter of the relevant age cohort are still at school at Year 12. Thus we have a situation where, at the stage in schooling when students are most likely to benefit from science education, most people are no longer at school.

Of the separate sciences usually offered to students at these levels, the most popular choice by far is now biology. Nowadays about two-thirds of the students continue at senior secondary level with some work in science, and this is usually biology. Other subjects tend to hold similar total numbers of students to those of a decade and more ago. The group still at school is likely to include most of the future community leaders, but only a minority of its citizens. Whether those who remain are the real 'decision-makers' is unknown.

The New Curriculum Movement

At the end of the 1950s, following the orbiting of Sputnik I, considerable funds were set aside by the US Congress for the upgrading of science education in American secondary schools. A perceived solution to the problem of a relatively ineffective school science education was to call together widely representative groups of scientists, science educators and teachers to devise packages of curriculum materials for both the student and the teacher. The idea was that a well-designed package of teaching materials - incorporating reading matter, practical work, audiovisual material and so on - could help the teacher present worthwhile content in a way thought most likely to achieve the main aims of a science education. They were marketed in a field already dominated by commercially published textbooks which, in general, were more conservative in their teaching approaches and modest in their aims, a primary goal being to present digests of scientific information rather than a series of learning experiences which would change not only student knowledge but their ways of doing things. The advent of the new 'alphabet courses' (PSCS, BSCS, CBA, etc.) led to their adoption or adaptation in other countries, or to similar efforts at materials development.

Seen in retrospect, after nearly 20 years of effort, the attempt to improve science education through materials production can be seen as only partly realising the hopes originally held for it.

In the United States, Britain and other countries which either took up the new programs or courses influenced by them, materials were widely purchased. Some of these were of sufficient quality to foster the intended aims; others were not. Many were used only in part, or fell out of use altogether. Today only a few of the original sets of materials still enjoy wide usage. Even where the materials proved appealing enough, the way they were used in the classroom was often very different from that intended by their designers, for a whole variety of reasons.

Yet the overall aims they espoused gained at least the verbal support of most teachers and science educators. Efforts have therefore continued either to try and improve these curriculum packages, or the ways in which they are implemented, or to seek alternative approaches to the same overall aims.

Two local cases illustrate these trends.

ASEP. For example, in Australia in recent years considerable financial resources have been spent on producing a package of teaching materials for junior secondary science. These became the Australian Science Education Project (ASEP) materials. They were prepared by a selected group of educators, and published through government agencies. In-service opportunities were provided for teachers to come to know the materials and improve their teaching skills.

The local experience seems to have paralleled the overseas one. A number of individual materials packages were prepared, and some of these have been widely sold. Junior secondary science classes in Australian schools now use either ASEP materials, other published materials, teacher-developed programs or a synthesis of all three. Junior secondary science classrooms vary widely in the teaching aims pursued, in the content chosen for inclusion, and in what students succeed in learning.

Senior Biology : The rise in the numbers of students taking biology in recent years is an interesting case. In 1967, about 3 per cent of Australian students at Year 12 took biology. In the 11 years which followed, the proportion of the senior student population taking biology rose to over fifty per cent, a change matched by no other subject in the secondary curriculum in that time. There may be lessons to be learnt from this very significant change.

The period of very rapid growth coincided with the introduction and dissemination of a set of student and teacher materials (the Australian Academy of Science's publication, Biological Science: the Web of Life) designed primarily to assist the teacher to fulfil the aims set out earlier. Its introduction coincided also with a reduction in or abolition of external examination and certification, increases in teacher and student decision-making about school courses, and trends away from vocationally orientated and 'difficult' subjects and for increasing proportions of the age group to remain at school, so the popularity of biology may have resulted from several of these factors and/or interactions between them.

After 11 years this attempt to try to assist school science education by producing teaching materials can be seen, again, as only partly successful. Although the numbers of students taking the program have been very great (approximately half a million), it is also clear that not all the aims of those materials are being achieved particularly well in many classrooms. Reasons may include the inherent difficulty of the task, the teaching methods used, the inadequacies in the materials provided, insufficient opportunities for suitable pre-service and in-service education, and deficiencies in the ways in which student progress at school is evaluated, in the time available and in other factors. Yet there appears to be general agreement amongst teachers and science educators that abilities to apply scientific understanding and scientific approaches to problems remain worth pursuing. This is simply a very difficult aim to achieve.

SOME IMPLICATIONS

If education is to serve particular purposes, it may need to be designed in ways likely to fulfil these purposes. Education for development means learning those things that will predispose the decision-makers' actions in the 'appropriate' direction at the appropriate time. It means not only new knowledge, skills and tools, but changes in attitudes too. The combination of these may be hard to develop.

If one accepts the proposition that national development depends on there being a large body of society's members able and willing to apply new developments in science and technology to their own situations, and that effective science education requires some maturity in its students, it follows that at least certain parts of that education be provided as late in formal schooling as the education system of a country will permit and to as large a proportion of that group of students as possible.

A scientific education appropriate for scientific and technological development seems possible, and could even become a lifelong process if the appropriate opportunities were to be made available and the students profited from them. But whether or not a student develops capacities to use what he or she learns is critically dependent on receiving a suitable range of learning experiences. This may be hard to achieve, even in a 'developed' society like Australia.

To educate someone in the making of informed, rational choices for the common good is not easy, and most efforts to do these things appear to have been only partly successful.

In Australia, and in many other places, central control of education has been greatly reduced in recent years. Much decision-making is being done at school or individual teacher level, making any kind of effort - such as improving science and technology education - very hard to implement nationally.

The idea of improving the effectiveness of school science education by producing suitable teaching materials seems to offer one way of helping to provide appropriate science education. But the materials themselves need to be of sufficient quality and closely matched to the needs of teachers and students. And the pre-service and in-service education of teachers need to be sufficiently good to enable them to exercise the responsibilities being progressively given to them. Unfortunately this is often not the case.

Thus, while it is undoubtedly true that school science education has been a factor in Australia's scientific and technological development in the past, and undoubtedly has the potential to contribute significantly to the scientific education of the community as a whole, the reality is something less than that. It may be that there will always be room for other means of achieving the education desired.

FOR CONSIDERATION

The paper so far has attempted to raise some of the issues thought important in considering science and technology for development. The questions below seem to arise from the above considerations.

1. Is it true that a modern society does not require many individuals capable of working at the frontiers of science and technology?

2. Is there support for the view that an 'enlightened' citizenry, capable and willing to apply science and technology to the problems they meet, should be the principal goal of a scientific and technological education program?

3. If the answer to Question 2 is either a clear or qualified 'Yes', then:

   (a) Should formal schooling be regarded as a primary vehicle for scientific education of that citizenry?

   (b) What can realistically be done to ensure that school students acquire the necessary attitudes, knowledge and skills in educational systems in which there is very little central control? And, for that matter, in systems in which there is central control?

   (c) Are there any other instructional media which can perform the same role as the schools, or supplement their role effectively?

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TECHNOLOGICAL TRAINING IN AUSTRALIA

BY

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In 1977, he was invited by the Royal Melbourne Institute of Technology to be its Principal and in early 1979 accepted a similar invitation from the University of Melbourne to become Deputy Vice-Chancellor.

1. INTRODUCTION

This paper indicates the directions that future education and training in technology should take for specialists in technological fields and other groups in society, especially decision-makers. It relates specifically to developments that are envisaged, planned, or may result from tecnical evolution.

Forecasts for the future are likely to be coloured by the experience and training of the forecaster and are particularly difficult in the present age when development is so rapid. It is now commonly believed that vocational training should be almost continuous or that planning should allow for two or more changes of career in a working lifetime.

Some attention is paid to the social impact of technology on groups and individuals. To neglect this aspect of technology is to avoid the major problems facing the many peoples of the world; in particular those in the most 'advanced' nations.

Initially, the paper briefly describes the development of training in the technologies in Australia. The second part reviews the changes over the years to try to pinpoint where mistakes were made or where omissions were most marked. Within the context of the problems of inflation, unemployment, and employment uncertainty caused by automation and the computer, the needs for the future are then mooted and discussed.

The term 'technology' needs comment. It is common to draw a distinction between the meaning of 'technical' and 'technological'. Usually, 'technical' is related to the trade or handicraft and 'technological' to the science of the industrial arts; the latter being more theoretically based. This distinction is evident in greater financial reward for the degree holder than for the skilled tradesman. It results in different levels and types of education meted out by technical colleges, advanced colleges, and universities and in different methods and levels of funding.

The distinction is examined here because of the impact of machines designed by technologists on trade training and the effect that variation in trade training has upon the starting point or background of the future professional engineer.

Technology has become attached to a large number of disciplines. While many professions use the term, it is the technologist in engineering that is most often implied when the term is used alone. This paper deals with this area in particular, except for some mathematical or systems aspects, and specifically, computer technology.

2. HISTORICAL SURVEY OF TECHNOLOGICAL TRAINING IN AUSTRALIA

Technological training, as it is now understood, has developed over a mere century and a half. Thus Australia is only 50 years younger than the advanced industrial countries if the end of the Industrial Revolution was the start of reasoned theoretical training in the technologies. The first university charter, in the non-discriminatory sense, was developed in Germany for the University of Berlin in 1809; the first professorships in engineering were established in various universities between 1830 and 1890.

Throughout the nineteenth century technical instruction was largely confined to the elementary principles of science and technique in places called 'mechanics' or 'technical' institutes. Almost all training prior to these institutes was in the crafts. The mechanics institutes were initially aimed at adult education for the tradesman rather than technical instruction, though as the century progressed the pattern of instruction changed. Technical teaching was spurred by the rapidly increasing number of inventions and discoveries in the latter half of the nineteenth century.

In Australia the early mechanics institutes were started in Hobart in 1827, in Sydney in 1833, in Newcastle in 1835 and in Melbourne in 1839.

The Universities of Sydney and Melbourne were founded in 1850 and 1853 respectively, but technological instruction did not commence in them until some 10 years later. In Glasgow, in Scotland, the first engineering chair was established in the 1840s. At the University of Cambridge in England, the first engineering professor was appoined in 1875 and in Melbourne a similar appointment was made in 1882. The Ballarat School of Mines commenced in 1870 and by the 1880s, New South Wales alone had nearly 70 mechanics institutes.

By the turn of the century, technological training in engineering was evident in Melbourne and Sydney, the Universities of Adelaide and Tasmania had been founded, as well as a number of technical colleges and schools of mines. Amongst these, Bendigo and the Institute at Geelong had come into being in Victoria, the former related to the mining development and the latter to wool and general technology. In 1879, the Sydney Mechanics' School of Arts founded a working mens' college, later to become the Technical College. 1887 saw the commencement of the Working Mens' College in Melbourne, later to become the prestigious Royal Melbourne Institute of Technology, its purpose being to serve the artisan population of the city. The South Australian Institute of Technology had its origins in 1889.

Technological training in Australia at the close of the last century would now be termed essentially technical though it contained elements of basic scientific theory. Design was elementary and largely by trial and error and rule of thumb, though based upon practical and experimental observation and proven successful practice. Overseas, the number and variety of inventions were expanding at a staggering pace wherein theory followed trial, experiment and intuition in more cases than it preceded it. New steels, new engines, the wonder of flight, painless operations, asepsis, the development of the wireless, the turbine, the motor car, submarines, steamships - all this was absorbed and transported to Australia to become incorporated into the teaching and instruction at the few universities and colleges, more often by immigrants than by Australians themselves.

Up to the late 1940s there was a steady development of the universities and colleges. The universities incorporated the wider educational community of poet, philosopher, doctor and engineer while the colleges were more vocationally based. While the curriculum of one or two colleges approached that of the universities a gap was evident between the levels of qualification and philosophy of teaching. The universities, following tradition, tended to concentrate on scientific and mathematical principle with the colleges teaching by repetition, experience and by example. University instruction lacked sophistication in its technological content while the technical colleges retained, as their base, the trade and established practice and built upon this. By the 1950s, the difference between the two types of institutions had resulted in the university trainee being oriented towards the managerial roles of his profession with the technical colleges emphasising the practical or trade requirements of engineering operation and skill. By this time, too, advancing knowledge emphasised the difference between 'technical' and 'technological' and the universities had moved into the research area, the colleges concentrating on what was available. However, technological research in Australia was considerably under-developed both in industry and university when compared with industrialised countries overseas; only government research establishments held their own.

Following World War II, Australia's rise in population, particularly the 17-22-year-old portion, the return of ex-servicemen and a steadily increased awareness of the value of education in the population, there developed a need for increased student places in universities and colleges to satisfy the educational aspirations of the people. As well, the number of tertiary institutions teaching an appropriately advanced technology was clearly insufficient in almost all States. However, from 1952 to 1959 the number of graduates per 100 000 of population fell from 43 to 36 compared with a rise of 37 to 50 in Sweden, 34 to 47 in France and a stable 96 in Canada.

The time had clearly come to examine the whole tertiary education system and, in August 1961, the Martin Committee was established to carry out the task.

Australia had always had strong links with the United Kingdom and many facets occurring there were often reproduced in Australia. In February 1961 a committee under the chairmanship of Lord Robbins was appointed to conduct a thorough investigation into higher education in Great Britain and to advise on what principles the long term development should be based. It reported in October 1963, about a year in advance of the Martin Committee.

The Robbins Report[1] contained a number of recommendations for the technological area which are worth noting.

Referring to institutions of technology at university level (of which Australia had none at that time):

(a) the volume of postgraduate work in science and technology should be considerably increased and, in particular, this should allow for the growth of postgraduate courses of study;

(b) a major effort should be made to encourage an increase in technological as well as scientific research;

(c) a number of university institutions devoted to high-level teaching and research, chiefly in science and technology, should be selected for rapid development. Imperial College (comprising mining, science, and engineering) and the Colleges of Science and Technology at Manchester and Glasgow should provide the nuclei of three such institutions;

(d) two completely new such institutions should be planned immediately; they like the first three should be constitutionally independent.

Referring to colleges of advanced technology (of which Australia had three or four at that time, called Institutes of Technology):

(a) these colleges should in general be designated as technological universities, with power to award both first and higher degrees.

(b) their emphasis should be on teaching and research in technology and science, but the development of other subjects should be encouraged.

All of these recommendations were implemented by the British Government.

The Martin Committee[2] in Australia made a large number of proposals only a very few of which were implemented by the Government. The following recommendations were amongst those rejected:

(a) that there should be no new university set up in Australia until after 1975, that is in addition to the 15 existing or already planned;

(b) that the number of part-time students in universities should be reduced and that any expansion of external studies should be outside of the universities;

(c) that an enlarged Australian Universities Commission should cope with the balanced development of all forms of tertiary education and in particular the 'Institutes of Colleges'.

And the following, again amongst others, was accepted:

(a) in broad concept, the proposal to broaden, extend and set up new diploma type courses in an 'Institute of Colleges' in each State.

(The Institutes of Colleges were to coordinate the work of the diploma-awarding technical colleges and upgrade them).

Following the Martin Report, two separate Commonwealth authorities were formed, one for the universities and one for the colleges, and these acted largely independently of each other. As well, nine new universities were established instead of the five contemplated; degree courses were approved in colleges but research was not funded; parity of remuneration between university and college staffs at various levels developed; and there was widespread duplication of technical equipment.

Colleges diversified their courses, college and university faculties expanded their numbers, sometimes in competition, drawing on a stabilising overall population which had an increasing appreciation of the value and need for tertiary study. Available facilities and staff grew to proportions, and in ways, that came under severe challenge in the middle 1970s.

Between 1965 and 1975 the colleges experimented by introducing studies in applied psychology and humanities to the various technological and vocational streams. Denied research funds by popular consent, they moved closer to industry, commerce and government. In diversification the universities came a bad second and in a strange way almost moved away from the community they served.

The development of the colleges was broad based and many new institutes were established across the country. An equitable distribution of funds to a large and small city and country college alike resulted in the development of the smaller colleges at the expense of the larger. No university or college was selected for special funding in the technological areas as education was developed on a wide front. An increasing number of graduates were brought to the same level and no one institution assumed a leading position technologically. The refusal of the Tertiary Education Commission to recognise funding for the colleges for applied research, though the teaching was at degree level, was a major facet of the 1965-1978 era.

By 1977 Australia was committing well over $1000 million to tertiary education, with some 140 000 undergraduates at universities and about the same number in colleges. Funding changed in the early 1970s. Instead of matching grants from Commonwealth and State there was complete Commonwealth funding and only service fees for student unions and service facilities were charged. The rapid 10-year expansion placed a heavy strain upon the community to provide suitably trained staff at the appropriate level. Even though recruiting was international the supply of staff from overseas was difficult as similar expansions of facilities were occurring in many countries.

By the mid-1970s the numbers of students each year were stabilising. While financial support continued, the rate of increase was effectively reduced due to inflation. The educational boom was slowing and the community was becoming more critical of the output from the system it had itself advocated; disenchantment among the general public began to emerge.

The time of consolidation, 1976-1979, was at hand, the expansion was over. Closer supervision by the States of the facilities funded by the Commonwealth and the way the facilities were to be used was mooted in various government, public and educational quarters. One Tertiary Education Commission, instead of the divergent two, was created. The upgrading of many technical colleges had opened up a gap between the degree or diploma holder and his technical and manually skilled counterpart. A special Commonwealth subsidy, Technical and Further Education (TAFE), was introduced to assist the neglected State-funded apprenticeship and trade area. A Commonwealth committee to formulate planning for the future was formed under Professor Williams, Vice-Chancellor of the University of Sydney, and was preceded by similar investigations in all States.

Overshadowing this examination was a set of circumstances which threatened to be very far reaching.

World-wide inflation in the middle 1970s coincided with the threat of diminishing supplies of oil to service the modern world's transport and power demands. In technological terms, the question of energy supplies for future generations caused world-wide examination of oil, gas, nuclear, solar, wind, tidal and coal energy supplies. Systematic plans were demanded and an energy policy became a necessity.

Following inflation came the rise in unemployment in Australia and many other nations. The cause is still not clear - many reasons have been advanced and some or all could have contributed. They include lack of confidence by employers in the future and the consequent reduction in staff recruitment; greatly increased full-time employment of women; a decrease in international trade; automation and the replacement of people by machines; over-taxation and removal of incentive, particularly at the senior executive level; and increasing strain placed on leaders, with a consequent lack of the will to fully extend. Facets of the last include trade union activity, the demand for productivity, staff conditions and performance, government performance, legislative restrictions and penalties, and environmental requirements - a bewildering set of demands which reduce the will to succeed and tend to encourage abrogation of responsibility.

The last, and possibly the most far reaching modern development to influence technological progress, education, employment, and vocational training is the advance of the computer. Steadily introduced into almost all facets of industrial, educational, commercial and governmental administration, the impact of the computer, with its capacity to handle, store and calculate all manner of information, has been startling. Although the computer creates some specialised job opportunities, it threatens the displacement of other staff, and poses additional problems of enormous moment for modern society.

The development of computer technology has affected engineering technological training for over 10 years in Australia. The teaching of mathematics in schools has been gradually modified and augmented so that computer language can be more readily understood and used later. Tertiary education courses first introduced short instructional programs followed by example and usage in the later course years, particularly the third and fourth years of degrees and diplomas. The gradual change in format of technological education from lecture and examination to more analytical and project-type work readily absorbed, used, and extended the scope of technological experiment and analysis. Instruction in computer language and its use now occurs in the later school years and in all years of tertiary technological courses. Syllabuses are being rewritten. Analyses and theory previously only soluble by laborious manual method are now, as a result of computer usage, straightforward and correspondingly more accurate and informative in result. Postgraduate research work in technology utilises the computer as a conventional tool while not displacing the need for a clear understanding of first principles.

The planning and development of technological training in Australia is examined in the next section with a view to pinpointing where omissions occurred and where modification could have produced different patterns or progress. The object of this is to help define the necessities for the future and the corrections or change of emphases that seem indicated.

3. REVIEW OF TECHNOLOGICAL PLANNING

Planning and evolution of technological education and training since the Second World War have produced in Australia a common standard between university graduates and between college graduates. The general standard of education from both systems is high and the difference between the university and the college graduate is not great. Graduates are comparable with their United Kingdom counterparts, analytically generally in advance of first degree American graduates, and their courses have been rather more analytically based than those leading to the practice-oriented qualification of northern Europe. Some universities have a higher academic standard of entry and education than others. The standard of the latter is very similar to that for colleges, which place more emphasis than universities on the vocational type of training. Graduates from a number of the larger colleges, particularly those that concentrate on training for practice more than the universities, are most welcome by industrialists.

Since the middle 1960s, the Institution of Engineers, Australia, has published guidelines for the basic elements it sees as necessary for the training of a professional engineer. Although these guidelines are not dictatorial in any sense, they have resulted in a similarity of curriculum across the country. To qualify for graduate membership of the Institution all courses will have to consist of four years post-matriculation study by 1980 (or possibly 1982, for special cases), with corresponding lengths for part-time and sandwich type training. Aspiring trainees are already showing preference for the four-year degree instead of the three-year diploma, which is fast disappearing. The superiority of a particular institution is likely to be due to the staffing standard demanded by that institution and, in general, staff applicants tend to favour the longer established institutions. This preference is also evident in application for places for study by students.

What Australia does not have is an outstanding technological institute comparable with say, Imperial College in England or M.I.T. or Caltech. in America. Stated simply, this is because no one college or university has been planned and specially funded for technological excellence. While the general standard is sound, no A.N.U.-type planning for technology has taken place. Clearly, certain departments in a number of universities and colleges are strong, but even they fall short of what could have been achieved if a Robbins-type recommendation had been adopted in Australia. Correction of this omission of technological excellence in education is long overdue.

Another error was the creation of separate commissions for university and college instead of one Education Commission to supervise the development of all forms of tertiary education. The dual commission system probably led to unnecessary funding between 1965 and 1970 and certainly to unnecessary duplication of facilities and courses. The benefit, of course, is that now there is certainly no shortage of facilities and places for technological training. The recent creation of a single Federal Tertiary Education Commission will hopefully overcome the duplication problems.

The influence of the Institution of Engineers' decision on four-year tertiary courses is interesting and has been controversial. In essence, the Institution declared that, irrespective of the standard of teaching or the capacity of the students, it was not possible to satisfy the basic training requirements for graduate professional engineering in less than four years. The most lowly advanced college or the best endowed university is governed by this time restraint if Institution course recognition is sought. In educational terms, the

Institution may have been too ambitious (or, at worst, too careful) in its determination to protect the profession's standards. The impact on technological education of three other facets of the post-war years in Australia is worth noting. The first was the State decision to allow advanced college staffs to instruct to degree level without Federal funding for work in applied research or development. In academic terms, such a state of affairs is not tenable. It can be argued that private industry and commerce should contribute funding for such work since it is these areas that derive direct benefit. For certain individuals and occasionally colleges, the practising community provides such support, but it is, at best spasmodic and, at worst, demonstrates an unwillingness to assume a responsibility which it is believed, or hoped, that the Government will shoulder.

Similarly, with certain notable exceptions, a great deal of industrial and commercial research takes place in parent organisations outside the country. New methods, procedures and knowledge are bought, or brought in from abroad. In the short term, this method of operation is often cheaper, but it denies the build-up of centres of knowledge within Australia and, worse, suggests that this is an acceptable policy. Such a situation places the maintenance of technological standard at risk.

The third development, since the Martin Committee's report in 1964, has been the fairly wide spread of Masters degrees, by course-work. Attempts have been made to define the different roles expected of universities and technological colleges. It is now generally accepted that the university's traditional role in fundamental research, together with the training element, is paramount and that the college role should follow a broad but vocational pathway. Professional training cannot be claimed as a preserve of the colleges since training in medicine, dentistry, engineering, law and other disciplines has traditionally occurred in universities as well as colleges. However, it is certainly not acceptable that course-work Masters degrees in the technologies, which are mainly teaching courses aimed at specialist vocational knowledge, should be the preserve of the universities, as they are at the present time.

Before discussing future needs, two additional circumstances of the present deserve some exposure. One concerns the detail of tertiary engineering courses and the coverage that is given to the social implications of machines, their products and their effect upon people, and the different city and country environments. Specifically, this is concerned with pollution, replacement of people by systems or machines, health implications of 'advances', repetitive task effects, ecological balances, individual control of one's own life, and the like. As the effects of technological advance have become more obvious, course planning has sought to include instruction in, and discussion of, all manner of such implications for the community.

This course planning has, in general, been of a patchwork or disparate nature. It has not received the detailed and close attention that is clearly necessary and, more importantly, it has not been systematically integrated into total course planning as it should have been.

The other factor is the technical knowledge, or lack of it, possessed by leaders in the community. This is important if leaders and managers are to make responsible decisions which affect the lives of people in an age when the machine, or system, influences all manner of living styles.

It is sometimes held that the trained scientist is not knowledgeable in the humanities or the arts and that the economist, historian or political scientist knows little of the technologies. True or not, when persons of any one of a number of backgrounds are placed in the position of formulating, or making, decisions of far reaching consequences for large numbers of people, particularly in matters affected by the technologies, it is important that they fully appreciate the consequences of their decisions.

Are skilled advisers any longer acceptable in such a scene, or does the effective power of decision then pass to the adviser? The penetration, for example, of massive financial or personal data in central computer banks is no longer a matter of understanding, or personal control, by the average senior administrator, who now relies upon relatively junior assistants for total reliability. The scope of such storage can no longer render such a procedure as acceptable, particularly since even the simplest data storage or program writing is a matter of mystery to many 'skilled' managers.

Such problems have been the subject of inquiry, both judicial and from a security standpoint, in recent years. The question of what technological background, and technical knowledge, leaders need has to date received little attention - a situation which is certainly far from satisfactory.

4. TECHNOLOGICAL EDUCATION FOR THE FUTURE

A fundamental principle in planning for the future is to try to ensure that the application of further technological advance is likely to be for the benefit - and not disadvantage - of mankind. Earlier-age problems of unemployment caused by the displacement of people by machines were not on a scale comparable with the vast implications of computer technology.

There have been moves in recent years by individuals and groups in many centres throughout the world to reject the less attractive features of modern civilisation and return to the 'simple' life. These moves are unlikely to succeed in putting the clock back. It is vitally necessary, though to be able to recognise the effects, both good and bad, of technological advance and, as early as possible, to reject or correct the undesirable and capitalise on the good. In many cases, however, it is difficult during the developmental stages to clearly discern likely, or possible, advantages or deleterious effects. This is often a fault of organisation and, often, unwillingness for representatives of all factions to present and discuss problems so that possibly improved answers can be found.

In proposing guidelines for planning for the future in technological education the following influencing factors should be considered:

- the need to carefully examine the current call for a system of continuous, or semi-continuous, education and training in the technological field;
- the basic education needed for such a system, or whether increased attention should be paid to a broad-based education encompassing, for as many as possible, solid groundwork in the humanities, science, mathematics and social studies;
- the need to build up an institute of technological excellence to serve as a centre for training at this level and to attract those who could examine, advise on and make contributions to new processes and advances;
- rationalisation of the advanced college and university sector (in the technological area) to minimise duplication of resources compatible with sound training of individuals. While universities must retain the freedom, in human terms, that is currently established, they must, in the technological area, pay more attention than hitherto to community need rather than staff desire;
- major improvement in administrative procedures between Government and university and college so that the financial planning is streamlined. In this area, guardianship of the public purse is important but should not be allowed, by its very method, to add millions in later years to the demands on that purse;
- careful examination of each branch of engineering technology, both in its training content and employment opportunity for the future. At present there is a tendency in the advanced colleges to separate branches at first year level rather than to build upon two or three years of wide general engineering principle so that later specialisation, as indicators emerge, can be more easily accommodated. The problem is aggravated by a lack of advance planning of quotas for admission of students in universities and colleges. The current quotas are a function of the staff employed in any one branch, at any one time, rather than of emerging future requirements;
- the lack of an appreciation of the wider social and economical problems in technological courses. Few graduates emerging from the present system seem aware that the effect of technological

> advance on the lives of the semi-skilled and non-skilled requires examination, or appreciation, of all manner of possible alleviating factors. Yet such graduates are destined to form an appreciable part of future top management in the country. The effects of early retirement schemes, job sharing, flexible work patterns, reduced working hours, stimulation of building and land care and development, the despair (or even psychiatric retreat) of 'unemployables', the reticence of manufacturers to support skilled trade training are all connected with technological advance - and must be recognised as such. A wider mode of thinking and more flexibility is needed and such topics should be introduced during the conventional early years of tertiary technological education.

This paper on technological training in Australia now discusses only the training system and course outline for the future in some detail. Other wider factors must be pursued elsewhere. While some affect course content and administrative procedure, they are not as relevant to those concerned with tertiary technological training as to those people who must tackle the problems of the sub-tertiary field and the young people who have no training beyond the middle years of senior school.

The broad lines upon which technological training in Australia is currently based are sound. While Australia lacks an institute of the highest technological scope and excellence, universities and colleges produce graduates and diplomates who, after a few years of practice, lose little in comparison with those of other countries.

As all technological fields become increasingly specialised and the need for a broader basis increases, it would be advantageous to draw the technical colleges, advanced colleges and universities closer together in supplying the proper training for the tradesman, technician, higher technician and professional engineer. There is a current trend to divide the technological training field into university, advanced college and technical college sectors. To meet the need for refresher, continuous or semi-continuous courses, and for occasional retraining, it would be an advantage to arrange this system into a continuous vertical pattern. Trainees could enter the pattern at a level that suited their current standard and leave when they have an appropriate training for needs or wishes. They could return to go further later on, or pursue alternative streams from an adequate and recognised starting point guaranteed by their previous courses.

The present system is not far removed from this. Some departments in technical colleges and advanced colleges work closely together and some universities are sympathetic to advanced or technical college entrants. But more acceptance of the value to the community of increased interchange and cooperation is certainly necessary. Some colleges still reject students who have failed at university and some university staff feel that their standard will be eroded by freer entry from colleges, forgetting that teachers at colleges are often more attuned to professional need than university staff. Similarly, university entrants from the matriculation (or sixth form) level would sometimes be better fitted, and happier, in tackling technical college certificate work. Again, it seems to have become much harder for an outstanding apprentice to progress into the professional training field than in years past.

Increased integraton, therefore, between the three types of institution should be encouraged and accepted as the norm, rather than separation into empires that then come to be defended.

Change in course content is again more a matter of regular fine tuning than drastic revision. Careful appraisal by the different academic authorities, with advisory groups, is needed to determine general objectives and content detail. Generally, the following aspects need attention: more integrated and systematic study of technological effects on various community values, less specialisation and a wider study of first principle in the early course years; and placing less stress upon examination or formal assessment of specialist work and periods and more on attendance and satisfactory field work.

It seems inevitable that courses will encompass even more computer technique and usage and that the electronics and systems analysis courses will develop the expertise needed to refine and extend computer application. The machine, new systems and the computer have replaced people in very many areas - book-keeping, shop attending, road making, telephone operating, and ledger keeping are simple examples. In most cases the new system creates the need for different job skills - packaging, advertising, data processing, programming and electronic maintenance are, again, typical examples. The technical colleges and upper school classes will need to take full account of the trend for those displaced to be in the semi-skilled, unskilled and clerical areas and for their replacements to require a greater knowledge of mathematics and basic and social science. Similarly, highly trained systems analysts and computer technologists need to be produced in greater numbers as the search for new fields is extended, and smaller, more versatile, greater range computers, are demanded.

Postgraduate degree training in the technologies is now due for a thorough appraisal. In engineering, in years past, PhD or Masters research training degrees demanded a full and careful critical appraisal of the literature - survey, design and construction of equipment, testing, analysis, retesting and summation. Now, references, surveys, and summaries of papers can be produced in hours by good libraries. Reference material has already been analysed and reported by authorities in countless areas. Equipment is now often available in complete units, rather than requiring the student to construct apparatus in local workshops. Computers do in minutes the calculations that took months in earlier years. Yet still the time spent by aspiring candidates remains unchanged and academic supervisors often demand long extensions for even the best students. Technological change has not produced any user saving in this area, though the pattern may have changed. Claims that the standards demanded in 1978 are higher than in 1950 would similarly be difficult to sustain.

Some attention needs to be paid to the training for non-technologists who need to assess various aspects of technological advance and understand the implications.

First, considerable attention should be paid to the coverage of general mathematics and science at the school level. Given the need for individuals to follow the path they prefer in career terms, it is quite astonishing how many high school students are turned away from comparatively easy subjects by a particular teacher's attitude or technique. Common faults are to recruit teachers at too high a level for the work required or to recruit teachers who are not devoted to a teaching career. Good teaching in mathematics and science at the third to sixth form level could solve many of the gaps evident in later life. While this is a particularly difficult problem to tackle and solve satisfactorily, involving as it does careful selection and transfer of teachers in particular areas, some solution is needed. For the technical schools, one of the main difficulties to be overcome is the idea that, in some way, technical school children are inherently less capable than their high school counterparts. This is also an extremely complicated area and needs study by educational experts to improve the currently unacceptable situation.

At the tertiary level, a careful examination should be made of the need to involve students reading philosophy, political science, economics, humanities and so on, in studies of the technological age in which they live. Ignorance of matters technical verges on a proud boast in some quarters but, in view of the possible consequences such an attitude is totally unaccceptable in the community leaders of the future. In the tertiary institutions this problem should be carefully examined by the syllabus planners, and solutions attempted.

For the rest, when retraining is necessary in later life, new information needed or special knowledge demanded, special courses in the relevant areas will be necessary. Planning for these, in the current Continuing Education schemes, is already established, but for organisational reasons is at risk. At present, 'normal' tertiary courses are free, continuing education is not. Normal courses are recognised as part of the lecturers' full-time load, but continuing education is not and is often a voluntary series of courses out of normal hours put forward for financial reward. Similarly, first diploma or degree students are eligible to receive a living allowance, while in general, extra qualification study at any time in the future receives no such assistance. Rather complicated guidelines have been drawn up which permit some students to take individual extra subjects free while others are required to pay. This situation arises as a result of the funding method under which tertiary institutions operate. The courses needed to refresh, to re-educate, to retrain, to specialise are available - the administrative procedures require careful and objective revision.

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WORKSHOP DISCUSSION

APPROPRIATE SCIENTIFIC AND TECHNOLOGICAL EDUCATION AND TRAINING IN AUSTRALIA

REPORTER

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1. INTRODUCTION

The general brief for this theme was to discuss appropriate education and training in science and technology for specialists. Special emphasis was to be given to appropriate education to allow effective evaluation of science and technology by all groups in society, especially decision-makers.

Since the brief for this theme was so wide it was originally intended to break discussion into two groups - public education and more specific science education and technological training. In the event, the two syndicates were combined into one.

The group considered Australian education more intensively than that overseas. Several members of the group were also able to draw on relevant personal experiences either in developing countries or in Australia in the education of people from those countries.

2. GENERAL APPROACH

In all aspects of these questions, Australia possesses, and is developing, a range of relevant models, some of which may be appropriate for cooperative ventures with developing countries. In general, we favour the following approach:

(a) people should be invited from developing countries to visit Australia to work in relevant educational organisations side-by-side with people sympathetic to, and knowledgeable about, the situation in developing countries;

(b) these visits would best be made by small groups - at least two people from each country in each group to minimise personal isolation and to maximise the usefulness of comparisons between the home and host countries;

(c) the emphasis should be more on offering our methods as useful models to adapt back home rather than on teaching a formal body of knowledge;

(d) encouragement of indigenous approaches to the development of education materials, policies and practices;

(e) an approach in all scientific and technological education, both in Australia and overseas, which confers a scientific way of thinking. Educators should strive to develop in their students the capacity to handle problems in relevant areas in which the students receive no formal training, rather than attempting to confer formal knowledge over a wide area.

These general features apply to each of the more specific sections following.

3. EDUCATION THROUGH ORGANISATIONS

(a) Schools

Basic literacy programs are vital to any improvement in scientific understanding and technical application. All cooperative programs of a scientific and technical nature should incorporate elements which seek to satisfy the urgent concurrent need for improving basic literacy.

Studies were quoted which supported the view that Australia has advanced to an international position in the forefront of science education and thus has much to offer in this field. There was concern, however, at the apparent drop in student interest in science subjects beyond the 14/15 year old level - other than in biology, perhaps.

Using the Australian Academy of Science's biology teaching project as an excellent example, the importance of indigenously developed teaching materials (viz. 'The Web of Life' book and associated aids) and teacher education was stressed. Programs of in-service training of teachers should be directed to those who already have some significant classroom experience in teaching science. This training, an integral part of the dissemination of a scientific attitude through the school age population, should concentrate on techniques and attitudes rather than the cramming of new facts.

For developing countries, Australia could offer to share our methods of writing new courses, but we should not seek simply to transplant our courses overseas.

(b) Post-Secondary Institutions

We were thus especially concerned with expanding the training of tradesmen, technicians, mechanics and the like. While not having formulated specific proposals, we agreed that greater emphasis should be given to assisting developing countries to expand their capacity for the high-priority task of educating a workforce capable of introducing and maintaining appropriate technology.

Training people at the higher levels of science and technology should emphasise the formulation and solution of problems. Adequate time for this approach can only be gained by shedding some of the cramming of facts which is all too prevalent in post-secondary courses. Higher education should seek to produce people with a sound understanding of cause-and-effect relations.

It is as important to extend throughout a nation the capacity to keep tractors, trucks and pumps working and to maintain electrical systems, as to educate a few highly trained specialists.

We were concerned at the tendency to emphasise the memorising of textbooks and the intolerance of any questioning of the authority of the lecturer, which can occur in educational institutions overseas. But, this also happens in Australian post-secondary institutions.

The value of work experience during courses was stressed, particularly for the vital contact with people that it affords. Though this is now common in the technology courses, it is seldom an essential part of science, courses. Professional education components should be incorporated in all courses.

Taken together, these approaches would better educate people to apply science and technology in an appropriate, practical manner, within the context of their own society.

Some members of the group were concerned at the standard offered at the highest levels within Australia in the education of engineers. It was observed that we still have to send some of our brightest students to overseas institutions for necessary postgraduate and postdoctoral experience in some fields. This reflects the fact that Australia is already behind the world, technologically speaking, and will be left disastrously behind if we do not act decisively.

Recommendation:

That Australia establish one centre of excellence for the advanced education of engineers at the graduate level and for research. This centre would best be added on to an existing institution.

(c) Continuing and Further Education

We stressed that the provision of better school and post-secondary education in both Australia and overseas is useful only if there is a parallel development in the continuing and further education fields (this term incorporating 'adult education').

As with school and post-secondary education, an appropriate approach needs to be tailored for the specific social and political structure of each country. We could not, nor did we wish to be, highly prescriptive in our approaches to overseas cooperation. We also recognised that there is a real problem in some countries of acceptability of those aspects of education which go beyond a strict curriculum, or which cut across the defined roles and perceived status levels of trained people in developing societies.

We therefore welcomed the recent shift by the Australian Development and Assistance Bureau to support visits by overseas people for short courses rather than solely for full-time, undergraduate-type training.

Professional refresher courses are now a vital component of the development of all specialist professions. For Australia, however, to adequately progress in this area in universities and colleges of advanced education, is dependent on clear guidelines being issued by the Government so that updating, refresher courses can be treated as a normal part of institutional operations. Currently, this activity has to be supported out of recurrent funds, with only partial recoupment through fees charged to participants. The designation of selected centres for such courses is favoured to maximise the use of resources and minimise duplication.

We believed that a few centres should be selected for expanded support in continuing and further education. The use of restricted resources would thereby be maximised and the duplication of courses offered would be minimised. Overseas visitors could find great value in participating in such courses.

The Australian-Asian Universities Cooperation Scheme was cited as a successful venture which could profitably be extended at modest cost.

A more general community education role in developing countries was also foreseen for Australia. Our nation is richly endowed with a network of great variety in non-government community organisations. Through attachments to appropriate organisations, Australia could specialise in offering continuing education opportunities to visitors. This would enhance their roles in their home countries as 'community animateurs', people who would facilitate the evolution of new ideas and the adaptation of ideas learned elsewhere. This may have relevance to the transmission of a better grasp of basic science and technology for health, production and community development generally.

4. INFORMING DECISION-MAKERS AND THE GENERAL PUBLIC

Ideas and information are only as useful as their effective communication to target audiences, and a matrix of communication networks exists for reaching these audiences. It is essential that specific audiences be defined and channels of communication to them be developed as an integral part of a strategy for a broad educational process in science and technology.

We supported the suggestion in the paper by Professor Jevons that decisions concerning science and technology should be shaped by informed public opinion including debate in the media. And, we recognised the existence among the public of a significant feeling of disquiet, and in some cases of active disenchantment, with science and technology and their effects. The media are currently not receptive to these views and when such popular ideas are reflected repeatedly in the media they can influence the decision-makers.

This points to the need for bolstering the existing private channels of communication between, for instance, advisory bodies and government, between professional institutions and government and between one learned academy and another with a concurrent program of expanding the channels of communication with the general public. This will not occur without some initiatives being taken to ensure that the public is adequately informed and that debate on issues is balanced.

Decision-makers are influenced by direct, personal communication and advice for specific proposals. However, in the political context, where social priorities are set, those concerned with the more effective application of science and technology also need to engage in a 'grapeshot' approach to secure the general public to their way of thinking.

We recognise the existence of a significant feeling of disquiet and, in some, active disenchantment with science and technology. The media are currently most receptive to these views.

Proposal for an Information Program

We strongly encourage non-government bodies involved in science and technology, notably the academies and professional societies, to take concerted, cooperative action to establish a National Program of Public Information on Science and Technology.

Some features of the program would be:

(a) Establishment of a National Science Centre, as proposed earlier by the Australian Academy of Science, including arrangements for travelling exhibitions.

(b) Reinforcement of public libraries and associated facilities with good scientific and technical material (including the generation and publication of such material in printed or audio-visual form).

(c) Provision to the media of popularly-oriented stories, story ideas, especially written series of articles and photographs for newspapers and magazines, and trained spokesmen for radio and television interviews.

(d) Encouragement of training in communications skills for professional scientists and technologists with protection for their professional standing while engaging in communicating with the wider public.

THEME 4

TRANSFER OF SCIENCE AND TECHNOLOGY

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INTRODUCTION

Dr Taylor discusses the various barriers to the transfer of science and technology from government research to industry, using examples from experiences of the CSIRO Division of Textile Industry. A good knowledge of industry and market needs and capabilities is essential for successful transfer. The ways a government scientist can acquire this knowledge are highlighted. Science management must establish clear objectives related to user needs and capabilities, and must ensure that the researchers continually keep these objectives in mind. However, this must be done in an atmosphere that does not stifle scientific creativity.

Dr Taylor maintains that, in the past, insufficient attention has been paid by government research to the important development and proving stages of an invention. This has largely been due to the high cost and poor status of development work relative to basic research. The different capabilities of staff in research and development must be recognised.

Problems of collaboration with industry in development arise from conflicts of the need for confidentiality with the wide obligations of government research and the pressures to publish. Other collaboration problems are inadequate definition of responsibilities, poor commitment, and poor communication. All those involved in collaboration need to recognise the importance of fairly sharing kudos or financial rewards from a development.

The general belief of CSIRO staff that publication is a major criterion in assessing suitability for promotion has resulted in undue emphasis on 'publish or perish'.

A development needs to be carefully nurtured through its proving stage, with the involvement of researchers, and problems with developments requiring high capital outlay at this stage need greater government recognition. Relationships with extension agencies are subject to problems similar to those encountered with industry collaborators. In general, Australian secondary industry has suffered from the lack of an intermediate 'extension' agency. Problems due to industry attitudes and capabilities are also mentioned by Dr Taylor.

Dr Davies' paper is the first of two papers from industry on questions of science and technology transfer by import to Australia, and his emphasis is on electronics and telecommunications. This industry is characterised by explosive growth and by a sometimes bewildering rate of change in the relevant technologies. The sequence from valves through transistors to integrated circuits, and then to optical fibre communications, in little over a quarter century is indicative of the rate of change.

THEME 4 - Introduction

In general terms, the establishment in Australia of technologies related to electronics and telecommunications has been based on development needs, rather than following from scientific advances. Dr Davies sees this as a natural consequence of our relatively small contributions, on an international basis, to world science and technology and of the small size of Australia's market base. The technologies successfully established in Australia have been strongly dependent on the presence of scientists, engineers and technologists fired with enthusiasm for the application of their background knowledge in industry. This has important consequences for Australian universities.

Dr Davies discusses various aspects of the problems associated with technology import under the above constraints. He sees a need for a much closer degree of interaction between government, education and industry sectors if most effective use is to be made of our opportunities.

The major issues singled out by UNCTAD as problems in the transfer of science and technology (S&T) to developing nations are discussed by Mr Kolm in the light of Australia's experience.

While all small nations import most of their know-how - as does Australia - their import/export balances differ widely. Australia's relative contribution to world science in terms of publications is far greater than her size (population or production of goods), but ranks low in the generation of technological proprietary know-how for her own economy and in the utilisation of her science in domestic manufacture; consequently Australia can be considered a strong exporter of science and strong importer of know-how. This is largely due to the structure of Australia's research and development (R&D): Australia's science is concentrated in the public sector, which has little involvement in the 'modern' manufacturing sector, and funding of industrial R&D by Government and private enterprise has remained low by international standards. This is reflected in a highly negative import/export balance of industrial know-how.

Mr Kolm analyses the visible costs and benefits of the import of technology qualitatively and in terms of royalty and dividend payments; the cost of visible payments appears low in relation to gross domestic product (GDP), to national expenditure on R&D and to the value of the technical information obtained.

The invisible cost of imbalance in the Australian R&D structure is discussed. Mr Kolm questions the linear model - 'science generates technology' - in relation to small markets; where scientific effort and industry are highly fragmented, local science does not coalesce into local technology. This leads to a gap between local science and local technology.

Nevertheless, the Australian development model has been successful. Liberal technology import during the import replacement phase has produced rapid and balanced industrial development and liberal support of science has produced a strong resource of scientific manpower, with great benefits to primary industries.

The disadvantages of the gap between technology import and local science emerge more strongly only now, as the period when import replacement was the driving force of development has come to an end. While import replacement will remain important, selective concentration of industry in some areas of excellence is now a key requirement. Australia's strongly developed scientific resources are mature and have the potential to contribute to this task. However, reorientation by both industry and research, particularly public sector research, is now needed if the structural disabilities resulting from the gap between technology import and local research are to be overcome.

Repco Limited's subsidiaries have, for some 50 years, been manufacturing automotive components in Australia. One subsidiary has been manufacturing universal joints in Melbourne for some 30 years. For a variety of reasons, covered by Mr Van Vugt, management decided to set up another plant overseas, at a cost of A$8 million, to manufacture universal joints.

The materials, tolerances, quality control and manufacturing processes used to manufacture a universal joint are highly sophisticated. However, it was decided that only two expatriates should be transferred, with all other executive posts being filled by local personnel, trained in Australia. It was further decided that only the latest in both product and manufacturing technology should be used.

Mr Van Vugt covers the main points of:

- initial research and analysis;
- negotiations with Governments;
- transfer of product and manufacturing technology from Australia and manufacturing technology from the USA, Germany and Japan into Singapore.

He also analyses the conditions necessary to attract and sustain investment in different categories of technology which will contribute to the development of a country.

The optimism shown at the 1963 UN Conference on Science and Technology for the Benefit of Less Developed Areas for the simple offering and ready acceptance of scientific and technological information has declined. Transfers of this nature are now recognised as being difficult and complex. New strategies are obviously required.

THEME 4 - Introduction

Generating self-reliance in recipient areas is generally regarded as the major objective of development. Science and technology are offered as means towards that end and not ends in themselves.

Mr Gurnett-Smith believes that administrative blockages are due, at least in part, to misunderstandings created by scientists and technologists. Scientific activities are often confused with technological application and are thus required to be justified in similar terms.

Scientists and technologists are now being called on to narrow the poverty gap paradoxically made wider by the application of earlier technological developments. To succeed, natural and social scientists need to collaborate and recognise the 'social functions' of science in preparing development plans. The danger of pressing forward with technological applications without attempts to generate a community-wide 'spirit of science' is stressed by Mr Gurnett-Smith.

Mr Gurnett-Smith makes suggestions for training scientists from developing countries to make them more effective. He calls for a better understanding in Australia of the problems confronting both the scientists and the administrators involved in effecting development assistance.

Dr Evans points out that problems encountered in the transfer of science are quite different from those in the transfer of technology. Science involves generalisation, whereas technology transfer usually requires local adaptation. Transfers to more and less developed countries also generate different problems. Agriculture and its supporting sciences are given high priority in requests for aid, and are prominent in our technical aid, partly because Australia is one of the few developed countries which practises agriculture under tropical and semi-arid conditions, with relatively low inputs, of direct relevance to many developing countries.

Dr Evans emphasises the need in technical aid programs for (1) local adaptation and the build-up of an indigenous, self-sustaining research capacity; (2) balance between scientific and technological development; (3) appropriate levels of technology; (4) integrated aid; (5) foreseeing the consequences, both technological and socio-economic; and (6) basing the technical aid, wherever possible, within the developing countries or regions. We all gain from such aid.

The discussion group concerned with the transfer of science and technology within Australia looked at the need for new technology, the development of Australian science and technology since World War II, the relevance of the post-war Australian scientific effort to technology generation, and at the present situation. The syndicate put forward a number of recommendations for consideration.

They covered the need for greater mobility of scientists and technologists in Australia and the need for improved receptivity. A direction of more of Australia's R&D effort toward high-yield areas was called for, as well as a closing of the gap between discovery of technologies and their application in Australian industry. Finally, this syndicate urged Australia's UNCSTD delegation to appreciate the complexity of the problem of transferring technology.

The syndicate discussing the transfer of science and technology to developing countries saw a need for a technical advisory committee to help brief Australia's delegation to UNCSTD. The group discussed the communication of Australia's transfer experience and recommended that the three Academies involved in the Workshop record that experience.

An integrated approach to development was seen as one way of avoiding the undesirable consequences of technology transfer. The syndicate discussed Australian research which is relevant to the Third World and recommended that separate funds be granted in aid of research relevant to the problems of science and technology in developing countries. Discussion also focussed on the problem of training Australians for working in developing countries and the training of counterparts in those countries.

SOME EXPERIENCES IN THE TRANSFER OF SCIENCE AND TECHNOLOGY FROM GOVERNMENT RESEARCH TO INDUSTRY

BY

D.S. TAYLOR

Dr D.S. Taylor, Grad. Dip. Elec. Comp., BA (Hon.), BSc, PhD, has been Chief of the CSIRO Division of Textile Industry, Geelong, and Chairman of the CSIRO Wool Research Laboratories since 1976. He has spent all his working life in textile research with CSIRO, having joined the then Wool Research Laboratories, Geelong, in 1951 as a Research Officer. He graduated with an honours degree in mathematics and a degree with first-class honours in physics and theoretical physics from Melbourne University.

He was awarded a CSIRO studentship and undertook research from 1952 to 1954 at the Wool Industries Research Association (WIRA), Leeds, England, which culminated in the award of a Doctorate from the University of Leeds. At Geelong, his research has ranged over the physics of fibre assemblies, friction and drafting, autolevelling and combing, alternative methods of converting staple fibres to yarns, high-speed spinning, and the wrinkling of wool. Nearly 50 publications have recorded the results of this work, many of which have been applied with beneficial effects in the world's wool textile industry.

Dr Taylor's contributions to textile science and technology have been recognised in the award to him in 1970 of the British Textile Institute's Warner Medal, one of the world's most valued prizes in textile science.

1. INTRODUCTION

The success of CSIRO in meeting its principal objective - to assist Australian industry by research - must be measured by the extent to which its inventions and knowledge bring practical benefit to industry. With certain of its research programs, there is no doubt that transfer has been accomplished and that the benefits have been high. While the overall benefits have fully justified Australia's investment in CSIRO, the incidence of research results that are not utilised extensively, or at all , is disturbing. The reasons vary with the project and the particular circumstances, and some will be highlighted in this paper.

Applied or mission-oriented research can be likened to participation in the British Grand National. The researcher with his project, like the jockey with his horse, has a long race to run, solving problems or jumping hurdles of various complexity. He is watched by the industry - or the crowd - sometimes supportive, sometimes openly hostile and unhelpful. When he comes to transfer what he has discovered to industry, he faces his Beacher's Brook, a hurdle that has brought many a good rider down. Even if he clears it, this does not mean that the race is won, for he has many more barriers to jump, albeit now hopefully with the crowd in stronger support. It is an outstanding jockey, horse and crowd combination that goes on to win the National, and it has to be an outstanding researcher, project and industry combination for successful innovation.

The problems that must be faced by researchers before actual transfer are not always scientific or technological. They relate to the management atmosphere, to the personalities of the researchers, and to the needs to be satisfied by the research program. Involvement with industry can again present personality problems, as well as legal and strong commercial considerations. Finally, fresh barriers of commitment and endurance, as well as further commercial, technological and industry problems, may have to be overcome.

This paper discusses the various factors that influence successful transfer. A very important point to make initially is that learning from failure is important to success. The paper is based on experiences of both success and failure, and I believe it prudent to use examples mainly taken from the experiences of the Division of Textile Industry. However, I believe that the transfer barriers discussed below are common to others involved in science and technology transfer from government research to industry.

2. KNOWLEDGE OF USER NEEDS AND CAPABILITIES

Well-known studies[1] have concluded that successful innovators are characterised by a strong awareness of user needs. With hindsight, application of common sense leads to the same conclusion. Unfortunately, it is not sufficiently recognised by some in mission-oriented research. Too often science has dominated and pushed an invention further than it would have been taken if user needs had been carefully researched and understood. As others have noted,[2] government mission-oriented research has problems because the scientist is removed from the market and has difficulties in understanding industry needs and capabilities.

Mistakes will continue to be made - just as industrial research scientists sometimes miscalculate industry needs[1] - but I believe it is possible for government research to establish sufficiently close contact with an industry to gain the industry and marketing knowledge required for successful innovation.

Knowledge and experience can be gained in a number of ways, in particular:

- direct contact by visits and through professional and trade associations;
- employment of people with experience in the industry concerned;
- staff interchange; and
- reading as wide a selection of the appropriate scientific and technical literature as possible.

The first three merit further discussion.

2.1 Direct Contact

Regular direct contact of mission-oriented scientists with industry is of prime importance, and should increase as the management responsibility of the scientist increases. Industry confidence in the scientist's ability must initially be built up, often by carrying out trouble-shooting - helping to solve some of industry's day-to-day problems. However, with an organisation such as CSIRO the amount of trouble-shooting needs to be carefully controlled.

Contact with industry also brings with it responsibilities. The management of a company may fear disclosure of their techniques and problems to the management of the next company the scientist visits. Consequently, it cannot be stressed too often that confidentiality must be respected. Naturally, this can present difficultues when problem-solving for another industry contact, but the temptation to disclose competitor techniques must be strongly resisted, otherwise confidence will quickly disappear.

Industry advisory committees help to maintain an awareness of user needs and capabilities. These can be very valuable as sounding boards for assessing the appropriateness of research and, occasionally the potential of a particular development. The Wool Textile Research Advisory Committee of the Australian Wool Corporation, which reports to the Minister for Primary Industry, has made many constructive comments on our programs over the years.

However, the researcher must maintain control over the direction his work takes, and advisory committees must remain advisory. Unless this control is retained, the short-term problems of the industry tend to dominate, and major innovation can be stifled. For example, when we started work on the effects of blending synthetic fibres with wool, there was strong opposition from most of our advisers and, in particular, many powerful woolgrowers. Pressures continued to be applied until, following a policy change in the early 1970s, positive efforts were started to promote the use of wool in blends. The knowledge we had acquired and were able to disseminate has undoubtedly helped this promotion.

Other means of assessing the significance of research are desirable. The Division has been fortunate in recent years in having access to the International Wool Secretariat's R&D Advisory Group and their economic assessment unit. Although we regularly carry out our own cost-benefit surveys, independent assessment can often be beneficial. The IWS unit, for example, recently carried out cost-benefit surveys of two of our projects which had reached the development stage. As a result, resources devoted to one project were significantly reduced and re-allocated to the second.

2.2 Employment of Industrially Experienced People

Employing people who have worked in the relevant industry can be invaluable, especially for the later stages of development. However, a correct blend of experience and creativity has to be established as it is often the man with a sound training in the basic sciences who provides the completely innovative ideas. The Self-Twist development[3] (Case Study 1) can be used as an example. The principle was established by a scientist with no practical experience in the wool spinning industry. The development of the spinning machine itself, however, involved people with basic, textile and industrial engineering experience. Similarly, at the very important stage of assessing the potential of the products of the prototype machines, textile scientists with many years of practical experience in yarn and fabric properties were involved.

2.3 Staff Interchange

Secondment of staff to industry or vice versa can be very beneficial both in broadening knowledge about industry and research and in transferring developments. In 1977, we were able to induce the research manager of a major British wool textile company to spend three months in our laboratory. The staff learned much from him, and he in turn completely changed his self-admitted bias against 'white coats', and recognised the pragmatism of people other than those actually subjected to the daily realities of industry. Now, largely through his influence, his company - a major customer for Australian wool - is installing a recent important development from the Division.

However, there are problems with interchange. Many companies are reluctant to part with their key men for a worthwhile period. They should be encouraged, though, to make short-term sacrifices for potential long-term gains. Personal and financial problems also arise through relocation, with the problems of running two homes, and sometimes separation from family.

3. OBJECTIVES AND PRIORITIES

Clearly defined objectives and priorities are a prerequisite to application of research. For example, research on the interaction of polymers with the surface of wool fibres could be done with the objective to build up knowledge for its own sake. When the purpose of the work is to help industry, the objective becomes one of understanding the surface chemistry to, say, improve or develop a cheap shrink-resist process which uses common conventional textile equipment and the type of labour and other services already available in the industry.

Research management needs to ensure that such objectives are always kept in mind, while creating an atmosphere conducive to the individual creativity so necessary for productive research. Certainly, the scientist must be allowed freedom to wander in thought and deed. However, when application is the objective, research management must not hesitate to pull him back to earth if it appears that the wandering is leading to something impractical or economically unreal.

4. DEVELOPMENT AND PROVING IN GOVERNMENT RESEARCH

There is mixed opinion on how much government research should be involved in the 'development' stages of an invention. I would maintain that, with some notable exceptions, insufficient attention has been paid by CSIRO to development and to the very important proving stage. There are two reasons for this.

Firstly, the historic attitude of fundamental research establishments throughout the world has given scientific development a 'second-rate' connotation. There are usually fewer opportunities for prestigious and, especially, prolific publication. As well, the kudos for taking an idea or new principle, which may not be the scientist's own, through to application has not been as great as that derived from originating the idea.

Secondly, development is often much more expensive than the research on which it is based. Research results may look good, but the road to successful development is long and consumes enormous resources.

The second-rate connotation of development is totally unjustified. In fact, I believe in many ways it needs a better scientist to do mission-oriented research and development. Basic scientists can aimlessly wander, stumbling upon new facts to become a success. In contrast, the mission-oriented and development scientists must hit specific targets to be successful.

As to expense, both research and development are essential for successful transfer, and there is no point in the one without the other. Since many sectors of Australian industry seriously lack development capabilities[4] government research must work worthwhile results through development. The additional money can be found in two ways: a greater overall allocation of funds, preferably with industry contribution, or reassessment of priorities and re-allocation of resources away from strategically orientated programs. The second option should not be dismissed lightly as Australia has a vast store of basic knowledge which has not yet been utilised.

Because of the importance of development, I believe it is worth while to outline the general route taken by an invention at the Division of Textile Industry:

- invention;
- laboratory evaluation and debugging;
- pilot-scale evaluation and debugging in the Division's mill;
- secret full-scale evaluation and debugging in 'friendly' mills in industry, normally in Australia first and then overseas with the help of the International Wool Secretariat;
- general extension in Australia via the collaborating supplier, if it involves chemicals or machinery, and/or the Australian Wool Corporation; and
- general extension overseas, again via the collaborating supplier and/or the IWS.

At each stage, different problems are inevitably encountered and have to be overcome before substantial resources are devoted to the next. The greatest problems in transfer are compatibility of personalities, dedication to the project, and a willingness to share both the traumas of the problem and the satisfaction of success.

4.1 Staff Capabilities in Research and Development

It is important to recognise that some scientists have greater talents in the basic sciences, and others in development. Thus, the actual inventor may not retain a substantial involvement much beyond the initial internal pilot-scale stage. However, it is essential that the professionals involved in the pilot-scale work maintain close association with the development through to the industry trials and the early introduction to industry. Solving problems at this stage usually requires the approach, logic and accumulated experience of the scientist if the innovation is to be successfully introduced with the minimum of time and expense.

The development of the Sirolan BAP (Case Study II) shrink-resist process[5] illustrates these points. The initial problem was to develop a polymer that could be applied to wool fabric from conventional water-based textile equipment to give shrink-resistance. Elegant chemistry by polymer chemists at the Division of Protein Chemistry produced a means of solubilising commercially available polyisocyanates. Evaluation trials with one of the most promising of these resins led to the discovery that mixing this resin with one of several commercially available water-dispersible acrylic resins gave improved shrink-resistance at much reduced cost. A Division of Textile Industry scientist who collaborated in the trials took the resin mixture into carefully selected companies in Australian industry for evaluation and debugging, during which he built up considerable expertise in applying it to different fabrics from many different types of machines. After debugging trials, collaboration was extended to the IWS Technical Centre in the UK where further trials were conducted before the process was launched world-wide. Now, two years later, the process has made good penetration in wool markets in 18 countries. Both sets of scientists were chemists by background, both had different types of personality, and neither could have done the other's job.

4.2 Collaboration with Industry in Development

It is not easy to recognise the stage to begin direct involvement with industry on a particular project. Much depends on the type and complexity of the invention, the type of expertise, particularly in formal research and development, of the potential collaborator in industry, and the nature of the industry being served. Premature involvement can be disastrous with a complex development. Thus, it is very important for the scientists to analyse carefully what they have achieved and be as realistic as possible in their assessment of what is still required, pessimistically looking for problems that are likely to beset the development. Above all, if they decide that the time is right for collaboration, they must ensure that their collaborators are fully informed of the scientific and technological problems which are known at that stage to require solutions. Trust is of the essence.

4.2.1 Selection of Partner - Comparison of two developments will help to illustrate some of the factors that must be considered in deciding when and with whom collaboration should take place.

The first is the Self-Twist machine already mentioned (Case Study I). This enables yarn to be spun at 300 metres/min compared with 15-20 metres/min by conventional means. The second is the Lo-Flo scouring system (Case Study III),[6] which makes use of the chemicals already present in scour waters to facilitate removal of the contaminants from the waters.

Self-Twist was a complex development, necessitating production of a high-precision machine with many engineering problems to overcome to achieve the anticipated productivity advantages. It also required a major effort to assess and develop the potential of the product from the machine. Conventional products had to be made from the unconventional yarns produced. As well, conservatism in the industry had to be taken into account. Consequently, production prototypes were required to produce sufficient quantities of self-twist yarn for evaluation. This in turn required collaboration with a top-class engineering company, initially to produce the prototypes to our design but also with a mind to their improving the system further. The company, therefore, needed good research and development facilities.

On the other hand, the engineering required to put the Lo-Flo principle into practice was relatively simple and the final product was the same as usual. The machine was therefore totally developed within the Division before being offered to industry under licence by tender.

The tender system would have presented very serious problems with the Self-Twist spinner because it was essential to keep the development confidential until all aspects were fully examined. There were three main reasons for this secrecy:

- our patent cover at the stage of involvement of industry was only first generation;
- premature disclosure would have had adverse commercial effects on the textile-machinery industry;
- the heavy investment of any company which became a partner in the development had to be protected.

The need for confidentiality, however, can cause problems. CSIRO has certain obligations to ensure that any Australian company has the opportunity to compete for the chance for involvement in development. This is a serious dilemma, and there is no simple solution.

In the case of the Self-Twist spinner, the solution was to keep the development secret. To select our collaborators, we short-listed a number of Australian precision-engineering companies, inspected their facilities and, with Ministerial approval, eventually selected Repco.

With Sirotherm, the development was advertised. As Weiss[7] has pointed out, many of the major overseas competitors of the Australian-based company that was eventually granted the development were made aware of the project and its state of development.

This kind of action can seriously aggravate relationships with the collaborating partner. They may be committed to considerable investment, which must be protected, yet advertising gives their competitors a clear picture of the state of the art of the project. Competing inventions can be developed or easy exploitation of the advertised development can be made legally difficult. Fortunately, attitudes are changing, and it appears CSIRO in future will have greater freedom in the method of selecting its partners.

4.2.2 Responsibilities, Communication and Commitment

Three prerequisites to success in collaboration between government research and industry are:

- the state of knowledge of the project and the future responsibilities of each partner must be clearly defined at the outset, and regularly reviewed so that misunderstandings are avoided;
- clear communication lines must be established. While formal committees are useful,[7] it is essential that researchers on both sides feel part of the same team. In particular, there should be open access to each other's reports and facilities; and
- commitment should be high on both sides.

None of these is easy to control, because so much depends on the personalities involved.

Again, the development of the Self-Twist spinner illustrates the importance of these points. Prior to any formal agreement, Repco undertook to build three prototype machines to our specifications. Subsequently, we realised that different mechanical techniques could at least double the production rate of the machine. Although there were many engineering problems to overcome we were confident that this very refined new approach merited further exploitation. With Ministerial approval for an agreement for exclusivity if success was achieved, Repco agreed to commit themselves fully by investing money in the project.

Because of our textile background, and the complete lack of experience of Repco in textiles, further evaluation of the properties and performance of the product of the machine had to be done by us. Problems were encountered with engineering development because we were not fully aware of Repco's abilities and tended to over-specify. We had been caught by under-specifying on earlier developments but, with Repco, there is no doubt we went too far the other way. The situation improved dramatically when they solved a serious engineering problem that had been facing us. Relationships immediately improved; both partners now had made significant contributions; and the project became truly a joint one.

There was high commitment at all levels in the managerial and technical hierarchy of each organisation. In particular, Repco set up a special subsidiary whose sole objective was to exploit the Self-Twist invention. Thus the aims of the subsidiary and the CSIRO personnel involved were the same and there was no conflict with other company interests.

4.2.3 The Role of Publication

A clearly stated role of the CSIRO in the Science and Industry Act is:

> 'to publish scientific and technical reports, periodicals and papers'.

While it is part of the mechanism of science and technology transfer to industry, I believe its importance has been highly over-rated. The best means of transfer is undoubtedly personal contact. Unfortunately, publication has too often been regarded as an end in itself, whereas it should be a means of documenting the background information and simply explained practical details necessary for achieving use of the development by industry.

There is still a widespread believe that publication is all important. Thus, many scientists spend significant proportions of their working year writing up results instead of talking with, explaining to, or sometimes even cajoling their industry colleagues to make use of the results. I have no doubt that a scientist who takes the direct personal approach is more effective in technology transfer. His publications will be fewer, although probably more worth while and still containing substantial good science.

The requirement to publish can also cause serious problems in a collaborative development. As already mentioned, confidentiality to protect the collaborator's investment is essential. This may entail delaying publication, or even not publishing at all, with again the personal worry to the scientist about his promotion prospects. Fortunately, it appears that these factors are increasingly being recognised within CSIRO.

5. PROVING AND EXTENSION STAGES OF AN INVENTION

5.1 Proving Stage

Our Divisional policy on transfer involves, if possible, extensive industry trials before release of an invention. This policy has been formulated over the years through experience - often very traumatic! There is nothing more fatal than releasing an invention without significant secret industrial testing under as wide a variety of conditions as possible. The faults that are inevitably picked up in such trials occur publicly, and seriously inhibit acceptance even when the problems have been solved.

Another major problem with proving comes when high capital outlay is involved. CSIRO Development Grants have assisted somewhat, but normally the amount of money available only enables the project to be taken to, say, the half-sized pilot plant. Unless there are heavy economic or political pressures on industry to adopt a particular development, only a few Australian companies are prepared to risk major capital expenditure on the first version of an unproved plant. Lack of risk capital has been a major stumbling block with this class of development.

The limited funds now being made available for 'demonstration units' through the Department of Productivity should alleviate the situation to some extent, but further stimulus is warranted.

5.2 Extension

I have stressed the importance of 'debugging' at all stages from invention through development. The time inevitably comes, though, when a development is released. When a supplying company is involved, in our case usually a chemical or machinery manufacturer, it will hopefully market and service the development. However, the willingness and ability of companies to fulfil the technical service role vary considerably.

As a Division, we have received help in development, proving, extension and subsequent technical service from the technical and research and development departments of the Australian Wool Corporation and the International Wool Secretariat. The IWS, in particular, acts as our 'extension agency' overseas. Much of the success of the Division, particularly in developments aimed at wool-product improvement, would not have been achieved without the help of these two organisations.

The comments made about relationships with collaborating companies also apply to our relationships with the IWS and the AWC. Good lines of communication have been established. There is mutual awareness of research, development and promotional activities. Biannual meetings are held to coordinate research, and the R&D responsibilities of each body are clearly defined. Every effort is made to ensure that any kudos and royalties are appropriately shared.

The present relationship has taken many years of mistakes, realisation of mistakes, and compromise to achieve. It is crucial to attempt to create a feeling of joint contribution to the project. At times in the past we had taken development too far before involving the IWS and then found that they had been working on the same problem. To expect them, as we did, simply to take the development and market and service it showed a poor appreciation of the feelings and attitudes of their staff. We have found that interchange of staff at crucial times in development again has proved to be extremely valuable, especially in creating the feeling that the development is a joint one.

For Australian primary industry, Departments of Agriculture act as the interface between government research and farmers. I am sure that many of the problems in our relationships with industry, the IWS, and AWC occur in the relationships between them and the researchers.

This intermediate development and extension tier is missing for most of Australia's secondary industry. There can be little doubt that the industry has suffered as a result. However, the problems of establishing such agencies are immense, when the variety and fragmentation of many of Australia's industries are considered. Clearly it is important that a research organisation should be deeply involved in its own development and proving. On the question of extension we must be aware of the problems which could arise from centralising extension activities and we must also be aware of the need for the scientist to be closely involved with the extension worker. Extension is an essential part of the research process.

6. INDUSTRY BARRIERS TO TRANSFER

I have mainly concentrated on barriers in government research which aggravate transfer to industry. However, I have brought in, or implied the existence of, industry barriers. Because of their importance I will now list these industry barriers separately:

- Entrepreneurial skill introducing new technology is generally lacking in Australian industry. For too long, industry has either languished in antiquated technologies under the umbrella of protection or imported new technology. Apparently the will and the ability to recognise the potential of new technologies being formulated here is lacking.

- Because much of Australian industry is fragmented, many companies are too small to afford technological development staff.

- I have emphasised that we try to design an invention to meet industry capabilities. However, sometimes new skills need to be learnt - often both scientific and technological and managerial. The test of standards in Australian industry must be whether the extra skills are more readily acquired here than abroad. In our experiences, often they are not.

- Commitment from industry in collaborative development must involve a substantial sharing of costs. The community cannot be expected to meet an undue proportion of the bill when the benefits will go mainly to the industry or individual company concerned.

7. CONCLUSIONS

I have described barriers to the transfer of science and technology from government research to industry and have attempted to show how they may be overcome. Much can be done by research management to create the right atmosphere for successful transfer. Prerequisites are a strong awareness of needs, careful definition of objectives, adequate control to ensure that objectives are kept in sight while also fostering creativity, recognition of the need for appropriate protection of commitments in collaboration, recognition of the importance of development and proving, and compromise in sharing kudos and rewards in success.

None of these is more important than the other. Returning to the Grand National analogy, ignore any one and you will find it very difficult to finish the race. However, I would like to stress the last one - sharing success - because it emphasises that transfer involves people, their feelings and their aspirations. The objective of research is to help people; people are the core of research; and good interaction of people is the core of technology transfer.

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CASE STUDY I

SELF-TWIST SPINNING DEVELOPMENT

1960 Because of the productivity limitations of existing spinning methods applicable to staple fibres, a project on finding new ways of spinning was commenced.

1961 D.E. Henshaw discovered that if two yarns with alternating twist were placed side-by-side they would spontaneously twist around each other and form a stable torque-free folded yarn with alternating regions of ply twist. Prototype machines using an intermittent-nip technique or contra-rotating discs were constructed and produced yarn at 25 m/min. Australian provisional patents were filed.

1962 A series of laboratory-model disc spinners raised production to 50 m/min. Preliminary attempts to weave the yarns produced were unsuccessful. Other mechanical twisting methods using air turbines or vortex were investigated.

1963 Collaboration with Repco was commenced. G.W. Walls developed hyperboloidal twisting rollers with improved twisting efficiency, low throughput tensions, and an upper production limit of 80 m/min. Yarns produced were still unweavable. The basic structure was varied by phasing, addition of unidirectional twist (STT yarns), and the inclusion of fine monofilaments.

B.C. Ellis started to develop new yarn and fabric technologies to cope with the unusual basic yarn structure.

1964 Prototype oscillating roller machine produced yarn at 100 m/min. B.O. Lavery invented a hypocycloidal system for driving the oscillating and rotating rollers. First secret mill weaving trial failed due to variability in the yarn supplied.

A range of 44 STT fabrics was produced to demonstrate the effect of yarn properties on the final fabric.

1965 The new hypocycloidal drive machine was completed and the range of STT fabric types was increased to 120. Promising secret trials were carried out at Returned Soldiers' Mill and Valley Worsted Mill, Geelong. Special air bearings were designed by Repco to improve the precision of the oscillating rollers.

1966 A new machine incorporating air-bearings, hypocycloidal drives and a modified roller-loading system increased production rate to 220 m/min.

Repco Ltd started on the design and tooling for a commercial spinner.

Basic processing parameters were established for converting the new yarns to fabric.

1967 The first Repco prototype commercial machine was evaluated at CSIRO for durability and yarn quality.

Extensive secret trials were carried out at four Australian mills involving STT copies of conventional fabrics. Processing was satisfactory, but the fabrics were generally judged too harsh and work was intensified on fabric finishing techniques.

1968 Four Repco production machines were delivered and subjected to extensive running trials to evaluate durability and the quality of the yarns produced. Repco and CSIRO commenced work on the final modifications dictated by the results of these trials.

1969 Machine modifications were completed and the design was frozen by Repco Ltd. CSIRO completed a work study to define and optimise operative tasks and organisation procedures. Mill processing trials were completed and fabrics produced were accepted by industry experts as indistinguishable from conventional types.

1970 The Self-Twist process was released to industry in Australia and at the Textile Machinery Exhibition in Paris. Twenty machines were delivered to Platt International in UK for distribution in industry, training, and acceptance trials. B.C. Ellis visited England to assist in disseminating the new technology and to monitor the machine's performance. A serious defect emerged in the covering of the oscillating rollers, which was damaged by many European spinning oils. A program involving CSIRO, Platt International and Repco Ltd was started to formulate a new elastomeric covering. A successful patent action against Du Pont in the United States resulted in their agreement to pay throughput royalties for 20 years.

1971 C.A. Anderson formulated a satisfactory roller covering. The first industrial installation took place at Macquarie Worsted Ltd in Albury, Australia (10 machines). The Self-Twist spinner received the Prince Philip Award for industrial design.

1974 Repco Textile Machine Pty Ltd completed manufacture of 1000 Self-Twist machines.

1975	The Mark II Repco Spinner, operating at 300 metres/min, was released at the International Textile Machinery Exhibition, in Milan, Italy.
1978	Over 2000 Repco Self-Twist spinners installed in industry.

CASE STUDY II

SIROLAN BAP DEVELOPMENT

1968	J.A. Maclaren (CSIRO Division of Protein Chemistry) studied the reaction with wool of low-molecular-weight isocyanates and their bisulphite adducts.
1969-70	M.A. White (CSIRO Division of Textile Industry) was engaged in development and extension of a permanent-press process [based on invention (1969) of H.D. Feldtman and B.E. Fleischfresser (Textile Industry)] for garments using a solvent-soluble polyisocyanate - Synthappret LKF (Bayer).
1971	G.B. Guise (CSIRO Division of Protein Chemistry) discovered a way of making water-soluble bisulphite adducts of polymeric polyisocyanates (BAPs) - a vital step.
1972	G.B. Guise moved to the Division of Textile Industry and continued work on the use of the bisulphite adducts of commercially available polyisocyanates as shrink-resist agents for wool. G.B. Guise and M.A. White, in collaborative laboratory trials on the adduct of Synthappret LKF, observed that cheap, soft polyacrylate emulsions can be mixed with it to give much better results by an extremely simple application procedure.
1973	G.B. Guise continued background work on formulation variables, including synthesis of new products, and laid the foundations for several new processes still under evaluation (197[illegible]. Following promising laboratory experiments, M.A. White embarked on the development of a new process based on available polyacrylates and the adduct of Synthappret LKF made at the Division. IWS, having accepted overseas rights in the original G.B. Guise 1972 patent under the terms of the CSIRO/IWS Wool Patent Handling Agreement, started licence negotiations with Bayer (Germany) for manufacture of BAP.
1974	Following successful mill trials, the process was adopted in an Australian mill. Pilot plant for BAP was set up to study large-scale preparation and to supply material for mill trials pending commercial availability. Mill trials on various textile products continued and AWC involvement commenced. Dai Ichi Kogyo Seiyaku, Japan, approached CSIRO regarding manufacture of BAPs and started licence negotiations with IWS.
1975	M.A. White and New Zealand Wool Board introduced the process to New Zealand industry (treated fabric named

Aqualana). Routine production commenced in six Australian mills and AWC became involved in technical servicing. IWS and Bayer conducted exploratory trials and concluded manufacturing licence. Total fabric treated to date, 600 000 m.

1976 Bayer commenced manufacture and released experimental product 'Synthappret 4694'. CSIRO named process Sirolan BAP and released Report G.30.

M.A. White conducted mill demonstrations with IWS and Bayer technical staff in USA, Europe and Asia. IWS took over extension and technical servicing of the process throughout the world. Dai Ichi Kogyo Seiyaku concluded licence agreement with IWS and market Elastrons E47 and E32 for application to non-wool fabrics.

Fifteen tonnes of Synthappret was consumed to treat an additional 1 500 000 m of fabric.

1977 Bayer added the adduct to its commercial range under the name Synthappret BAP, and the process was adopted in numerous European and Asian mills.

CSIRO continued experiments on formulations for improved performance of specific products to expand the scope of the process. Details of an improved formulation were released.

1978 Process in use in 18 countries.

CASE STUDY III

LO-FLO DEVELOPMENT

In the period up to 1972, the C.A. Anderson and G.F. Wood research programs on wool grease recovery provided a background of knowledge of the properties of wool scouring liquors.

1965 Scouring experiments (C.A. Anderson and G.F. Wood) with restricted water input showed that the efficiency of scouring liquors is not affected by high concentrations of pollutants.

1972 It was observed that the addition of high concentrations of some detergents to scouring liquors sometimes caused destabilization of the liquors.

1975 The concept was formulated to achieve a high concentration of detergent to destablize the liquor (1972 result) by restricting water input (1965 result). A pilot plant operating on this principle was built.

1976 Additional work with the pilot plant showed that 'concentration destabilization' was caused by a combination of dissolved substances, of which suint (water-soluble sweat salts) is the most important and soda ash and detergent make smaller contributions. From this work the first Lo-flo plant was built at the Division of Textile Industry.

1977 The Lo-Flo process was demonstrated to industry at a special conference at the Division. Following tender, an Australian engineering company - Wessberg Martin Engineering - was granted exclusive rights for Australia and New Zealand.

1978 The first two commercial Lo-Flo plants started in mills in Brisbane, and Keighley, England.

SCIENCE AND TECHNOLOGY TRANSFER TO AUSTRALIA; BENEFITS, COSTS AND PROBLEMS - ELECTRONICS AND TELECOMMUNICATIONS

BY

L.W. DAVIES

Dr L.W. Davies gained his BSc from Sydney University in 1948, after war service with the RAAF, and his DPhil from Oxford University in 1951. He worked with the CSIRO Division of Radiophysics from 1951 to 1960, and has been in industry since that time. In 1965, he was also appointed Professor of Electrical Engineering and Head of the Department of Solid-State Electronics within the School of Electrical Engineering, the University of New South Wales, and retains that position while being Chief Scientist for Amalgamated Wireless (Australasia) Ltd. Dr Davies is a member of ASTEC, and of the NSW Higher Education Board.

Dr Davies' research interests have been primarily in semiconductor and device physics, integrated circuits, electrets and surface acoustic waves

He is an Officer of the Order of Australia, a Fellow of the Australian Academy of Technological Sciences, and a Fellow of the Australian Academy of Science.

1. INTRODUCTION

The Organising Committee for this Workshop has chosen two people from Australian industry to discuss the import of science and technology into Australia. It might be said that this is a fortunate choice, in that technology is for the most part established by, and located within, industry. Furthermore, the two people chosen represent complementary aspects of Australian industry. Their two companies are Australian and transnational, with their technology transfer primarily by licence and parent/company investment respectively (although there is always a strong local input to the local company's technology base). Both industries represented are two of the most strongly science-based, in explosive growth phases, and yet quite highly developed. It would be fair to say, however, that electronics and telecommunications are currently developing more rapidly than the chemical industry. It is certainly the case that the consequences for mankind of microprocessors and other sophisticated products of the electronics industry have caused close reconsideration of the social and economic consequences of technology development.

I will take it as read that the manufacturing industry plays an essential role in Australia. Without it we would have serious problems in employment and in maintaining our balance of payments, to name two elements only of that role.

2. SPEED OF TECHNOLOGY CHANGE

One characteristic of the electronics and telecommunications industry is the rapidity, sometimes bewildering, with which new devices, processes and concepts pass through the research and development phase to the stage of being incorporated in new equipment. Those of us who grew up with the transistor, still less than 30 years old, can recall the rapid sequence of changes: from germanium to silicon devices; from simplistic grown-junction and alloyed transistors to diffused and implanted planar silicon devices; and finally, from miniaturised circuits incorporating discretely wired transistors to integrated circuits of an extreme degree of complexity (microprocessors etc.), containing many thousands of transistors within a chip of silicon only one or two mm^2 in area. I can confirm Hill's identification of the speed of change. It is perhaps worth noting that matters can only become around a hundred times more complex than is currently the case before transistors reach atomic dimensions.[1]

Technical developments such as these did not occur because of a desire to be fashionable or to use the latest products of the imaginations of physicists or materials scientists. Rather, they occurred because engineers recognised that the small size and weight, the low power consumption, the potential for low costs and the reliability of transistors could lead to substantial improvements in the cost-effectiveness of designs. Above all, their reliability, together with their micro-miniature size, led to the incorporation of progressively larger numbers of diffused transistors and resistors into integrated circuits fabricated on a single chip of silicon. Their reliability enables LSI circuits containing tens of thousands of transistors to be fabricated successfully.

Developments which take place on such a rapid time-scale make the choice of appropriate new technology for application very difficult. Transfer to countries which have a need to implement the new technologies in, for example, telecommunications systems is even more difficult. There is, therefore, a need for the countries to which the technology will be transferred to be highly selective, to ensure that commitments to application are not made to particular aspects of the technology which will soon be superseded. It is clear that this particular problem can be surmounted only through the agency of a strong local base of scientists, engineers and technologists able to maintain awareness of the nature of international technological advances in their field through a local program of research and development which has been funded with that particular aim in view.

3. TECHNOLOGY AND DEVELOPMENT

The essential role of manufacturing industry in Australia has already been highlighted. Manufacturing industries are utterly dependent on having in their possession the technology or technologies involved in fabricating the product line on which they are currently engaged, or on which they hope to become engaged with the introduction of new products.

At both national and company level there is a need first to establish development needs. Having done this, the technologies which may be relevant or essential to achieve fulfillment of those needs can then be considered. Finally, one would give thought to what particular branches of science are relevant to the particular technologies which have been identified and ensure that one had access to personnel with expertise in those branches.

There have always been problems in identifying the development needs of potential users or customers. Sometimes these needs are common throughout the world, in other instances they may be particular to the Australian scene. I shall refer to some examples of development needs, identified in the past and which have now been met, in which these problems of identification may be more clearly seen.

Within electronics and telecommunications there are many examples of technology following development needs in Australia. One thinks immediately of the requirement for a beam radio service in 1927 to allow direct radio communications between Australia and the United Kingdom, rather than communication through an intermediate sequence of relay stations. The radio technology, and particularly the development of appropriate antennas (and the knowledge of how to use them), originated in Australia. A second, and more recent, example is the development of Interscan, referred to in the Australian National Paper for UNCSTD.[2] The technology concepts required for a successful microwave landing system were developed and proved in Australia in response to an international requirement, rather than to a strictly national need.

In World War II, there were many examples of desperately needed electronic components and equipment for which the technology had to be developed locally, in the face of inadequate information or in the absence of supplies of materials customarily employed. It was during these years that the inate inventiveness and self-reliance of Australians, described so vividly in general terms in Leo Port's recent book,[3] came to the fore in the production, within the electronics industry, of a great variety of avaition instruments, military radios and, particularly, portable advance-warning radar units.

Today there is still a need to maintain some degree of defence preparedness within the electronics and telecommunications industries in Australia.

This is not the occasion on which to explore in detail the full spectrum of procedures which might be adopted to maintain an adequate level of defence preparedness. In Australia, we have seen, for example, an attempt in the late 1950s to introduce the technologies appropriate to the manufacture of transistors. These attempts were quite successful up to the time of the abrupt reduction in tariff protection in 1973, which led to the economic demise of the industry. Fortuitously, however, defence support in 1968 for one element of the components industry, namely microelectronics and the manufacture of integrated circuits, has enabled that particular high-technology segment of the electronics industry to flourish in Australia, as well as a wide range of relevant technologies associated with it. Put briefly, the reason for the success of that segment has been the identification of a series of needs, within local industry primarily, which have required the design and fabrication of integrated circuits on a 'customised' basis which was too restricted to be of interest to large overseas manufacturers.

There is a need to identify electronic (and other) technologies in which local industry should be involved as a specific measure of defence preparedness. This is a matter to which completely inadequate recognition has been given, according to the Hamer Report.[4] That report goes on to recommend the identification of the range of electronic technologies needed, and the means of establishing them. The question must also arise, in the course of that procedure, as to whether it is more effective nationally for technologies required for defence purposes to be imported and introduced into the various defence research establishments or into industry, where they may be applied in a wider spectrum of activities.

4. PERSONNEL

In all the above, the key characteristic has been the need for scientists, engineers and technologists to be on hand for the establishment of the appropriate technology in Australia. It is important that the personnel concerned have strong technical backgrounds, often possessing higher degrees, but that they not be PhD scientists or engineers interested solely in pursuing further extension of the project on which they worked in the course of their PhD program. A major difficulty in achieving this state of affairs in the Australian scene has been the lack of any real commonality of outlook between those working in universities and those working in government and in industry. Industry does need men and women with a scientific and technical training, but it needs them to be fired with enthusiasm for applying their scientific and technical background to Australia's needs, and to the establishment of appropriate technologies to fulfil those needs. This 'indoctrination' must be commenced during undergraduate days, I believe, and implies that universities need a much greater awareness of the technical world outside. It might be said that Australian science appears to be locked too strongly into correspondence with the transnational scene, rather than into contacts with the Australian technological and industrial scene. There is a very great need for procedures to be built up which will ensure that workers in all three segments interact together much more strongly than has been the case in Australia since World War II. Perhaps a greater level of mobility between segments could also be achieved.

5. TECHNOLOGY FROM OVERSEAS

It is a fact of life, and one on which Kolm's paper has more to say, that by far the greater range of technology which will be put to use in Australia originates overseas. As already noted, this requires a bank of trained expertise within Australia, able to identify relevance and adapt the imported technology where necessary.

This is by no means the whole story, however. It is often assumed that the technological base already exists in developed countries from which countries such as Australia can select exclusively, to their ultimate benefit. A brief look at many examples from Australia's past will show that such a defeatist attitude was not adopted by our forebears!

6. GOVERNMENT CONSTRAINTS AND INCENTIVES

There are some instances in which government policy has worked counter to the introduction and maintenance of appropriate levels of technological awareness within Australian industry. One thinks, for example, of the long delays preceding the introduction of colour television in Australia in 1975. One consequence of that delay has been that the technology of colour picture tube manufacture is absent from the local scene. Other examples of counter-productive government policy include delaying the introduction of stereo FM broadcasting in Australia until 1976. This was some 15 years after the pilot tone stereo FM system was first used in the United States, and 35 years after monophonic FM 'went commercial'! Australia has still not moved to allow introduction of cable television, a service which has proved to be popular in other parts of the world. If it were permitted to be set up here it would give a strong fillip to the establishment of the appropriate technologies in Australia, including optical fibre communications.

These are examples of positive governmental opposition to the importation of technological applications; the actions of course had no influence on the development of the technology elsewhere.

On the other hand, specific government purchasing policy in certain areas has strongly catalysed the import and establishment of some technologies. An outstanding example of the effectiveness of such a policy is provided by Telecom Australia. In the year 1970-71 the Post Office, as Telecom then was, placed local orders for telecommunications materials totalling $A207 million, $A188 million (91%) of which was for supply of these materials by local Australian manufacturers. The increase to 91% local production in 1970-71, from approximately 30% in 1939-40, was the consequence of a well-established policy within the Post Office. It is of some interest to note the reasons for this policy. I quote from a paper presented in 1966 by Wright and Beckwith of the Australian Post Office.[5]

> 'The advantages of a locally based industry to supply the needs of an expanding telephone communications system in a developing country are apparent in the areas of national economy, defence and overall technological development. However, in the more limited Australian Post Office interests, the advantages are mainly in greater security of supplies, reduction in lead times for ordering, and flexibility to adjust delivery schedules to meet program changes. Another important advantage is the improved facility for liaison with manufacturers to adapt and improve designs to meet local requirements.'

The efficient and profitable telecommunications services provided by Telecom to the Australian public are an indication that such a purchasing policy can be pursued effectively in this country, and that it can also lead to the local establishment of important segments of technology.

7. CONCLUSION

The principal 'message' contained in this paper is that there are many problems in the establishement of electronic technologies in Australia related to our development needs. Those touched on include:

- the need for selectivity from a vast array of technologies (selection based on both commercial and defence considerations);

- the need for a base of appropriately trained personnel;
- the appropriateness of government constraints and incentives.

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SCIENCE AND TECHNOLOGY TRANSFER TO AUSTRALIA; BENEFITS, COSTS AND PROBLEMS - THE CHEMICAL INDUSTRY

BY

J.E. KOLM

Mr Kolm is a graduate (Ing. Chem. Eng.) of Prague University, where he lectured in physico-chemical methods. In 1950, he joined ICI Australia as Factory Development Officer. He was involved in the development of a process for gamma hexachlorocyclohexane ('Lindane') and diaphragm cells. Subsequently he joined the Research Department and was responsible for Planning, Agreements and Patents.

He is a co-inventor of the 'Tetramisole' synthesis, a veterinary drug which ICI Australia have licensed throughout the world. In 1970, he was appointed Research Manager and in 1973 became Executive Director. He is responsible for Research Technology, and Biologicals and is a Director of ICI Engineering, CSR-Chemicals, Nylex Corporation, and Catoleum.

Mr Kolm is a Fellow of the Australian Academy of Technological Sciences, Chairman of the Southern Region of the Australian Industrial Research Group, and a member of Technical Standing Committee No. 4 of the National Energy Research, Development & Demonstration Council.

> "The way in which man has come to understand celestial matters appears to me hardly less wonderful than the nature of the celestial events themselves."
>
> JOHANES KEPLER (1571 to 1630)

INTRODUCTION - FRAMEWORK

The title of this paper places it in the field of the economist or of the professional scholars of the science of science. However, in spite of recent scholarly efforts for example, by Spiegel-Rosing and De Solla Price,[1] Bradbury,[2] Moravcsik[3] and, in Australia, Moyal,[4] quantitative data are sparse, and of the 'tip of the iceberg' type. 'There is still an absence of solid generalisations based on reliable empirical data' (Brooks[6]). In addition, the data and socio/economic framework of most authors come from large industrial nations, with the notable exception, perhaps of Canada (La Montagne[5]).

In this 'soft' science situation, views from Australian industry may be able to make a contribution in that they represent:

- practical experience of technology transfer side by side with the creation of local technology;
- the views of a small country which is predominantly a technology recipient and is not a member of a large economic bloc;
- the views of two of the three most research-intensive industries - the electrical/communication and the chemical/petrochemical/plastics industry;
- the views of one Australian company and one international company with Australian minority shareholding and wholly Australian management.

Inasmuch as Australia's population, markets and share of the world's S&T are small, analysis may also reveal significant scale factors in S&T strategy which do not emerge from the conventional emulation of the major industrial nations, or of small member nations of the EEC. This paper deliberately focuses on the Australian experience. History does not repeat itself, yet the Australian precedent, in some aspects, may be relevant to developing economies.

The main problems confronting developing nations in acquiring technology have been summarised by UNCTAD as follows[7]:

- Technology transfer agreements relate to the modern fast-growth sector and hence dependence on these sectors will increase;

- The foreign exchange cost of technology transfer (patents, licensing, know-how, trademarks, consultancies) to less developed countries is substantial - $1500 million in 1969 and possibly $9000 million by 1980;

- Constraints imposed by the technology exporters, namely, reliance on expatriates' skills, thereby discouraging local R&D.

This latter point, the interaction between S&T import and local S&T, is of interest, particularly in relation to the tied purchase of raw materials, restrictions concerning export, and the terms limiting diffusion of purchased know-how within the importer's country.

Although UNCTAD's criticisms are addressed to technology import, there are analogous problems with science import. UNCTAD's points may therefore serve as a framework for discussing Australian experience. However, there are additional costs, particularly to the structure of the economy, and some balancing benefits, to which I will also attempt to do justice.

CHARACTERISTICS OF S&T FLOW

Before we come to the topic, the basic characteristics of the Australian R&D&T scenario need to be stated.

S&T Import/Export Balance

The fundamental starting point of an import/export balance is that virtually all S&T is international and communicable. Even the most geographically-bound technologies, agriculture and mining, have far more common features than local differences. The so-called 'modern manufacturing sector'[7] (Table 1), including chemistry/petrochemicals and electrical/electronics engineering, is particularly international and transferable. It constitutes the core of 20th century industrial growth and of Western prosperity. It is also the sector with which developing nations are particularly concerned and in which patents are important. The S&T import/export balance exhibits significant differences between nations on a population basis. These differences may be ascribed to local factors, including national creativity, opportunity, markets, resources, needs, accidents of history and policies. 'Unfortunately there are no direct ways of measuring ... technology' and science. Nevertheless, 'publication and citation counts have been used with increasing frequency' to measure science output[3, p 137] and 'the analysis of patent statistics is another of the crude but useful tools developed by economists'[1, p 200] to measure technological creativity and industrial muscle. The number of patents owned throughout the world rather than inventions has been suggested,[8] since it is a weighted parameter of international industrial rights (breadth of filing) based on the inventor's or the corporation's own assessment of merit. The extent to which Australia's publications and patents are above or below expectancy is thus one indicator of the S&T import/export balance.

There are, of course, many other methods of evaluation, particularly case studies. Mere enumeration of 'breakthroughs' are popular in the press, both lay and scientific, but they are not often supported with concrete evidence. Particularly after some time, sober data on new plants built, products sold or profits made are necessary before such claims can be given weight.

TABLE 1

Australia's Technological Balance of Payments
1967/68 to 1976/77

Year	Receipts	Payments	Deficit	Payment as % of GDP in Manufacturing at Factor Cost	GDP Total
		($A million)			
1967/68	6	64	-58	1.12	0.27
1968/69	7	63	-56	0.99	0.23
1969/70	7	68	-61	0.98	0.23
1970/71	6	64	-58	0.86	0.19
1971/72	4	56	-52	0.70	0.15
1972/73	4	75	-71	0.84	0.18
1973/74	5	66	-61	0.63	0.13
1974/75	9	75	-66	0.63	0.12
1975/76	8	75	-67	-	0.095
1976/77	13(10.6[g])	57(66.8[g])	-44(56.2)	-	0.05(0.07)

Figures are based on overseas payments and receipts for royalties and copyrights.

Sources:

(a) Balance of Payments 1974/75.
(b) Australian National Accounts 1975/76, Preliminary Statement No. 3.
(c) Gross Domestic Product at Factor Cost by Industry
(d) Australian Bureau of Statistics.
(e) 1967/68 to 1974/75 taken from B.L. Johns "Some Economic Aspects of Australia's Dependence upon Imported Technology", 1977.
(f) GDP Values taken from Australian Yearbooks, 1972 and 1976/77.
(g) Research and Experimental Development. Private Enterprises 1976-77, Aust. Bureau of Statistics, Feb. 1979.

With 0.35% of the world population, Australia accounts for 1.6% of its scientific literature, ranking 9th in absolute numbers and 6th per billion dollar GDP.[4],[9] However, Australia owns only 0.31% of the world's emerging patents, ranking 15th in absolute terms, 22nd per billion dollars GDP and 18th per caput. Australia has fully responded to its 'responsibility to carry out (and publish, free to all) a fair share of the world's basic research'[11, p 30], but far less effort appears to have been channelled into, or succeeded in, creating valuable technological property for Australia herself. (Statistical data are summarised in Table 1 and detailed in Tables 2 to 8 of the Statistical Appendix). Australia spends proportionately two to three times as much on basic research and about half as much on experimental development as either the UK or USA.[11]

The technological balance of payments (Table 1) reflects the same trend; our royalty receipts are roughly one tenth of our payments. (These data must be treated with some reservations, since a high proportion of know-how flows free and is not reflected in royalties.) In all these aspects, Australia differs from developed industrial nations.

Ratio of Public to Private Sector Research

Research performed in the public sector (government bodies and higher education) in relation to the private sector is unusually high in Australia. Using research budgets as the indicator, the ratio of public sector research to private enterprise research is 61:39 (Table 5, Statistical Appendix), that is 1.56 to 1. Employment figures[19] quote 38 009 researchers in the public sector for 14 710 in the private sector, that is a ratio of 2.7 to 1. This compares with an average 0.9 to 1 for small nations (Belgium, Canada, Finland, Holland, Norway, Sweden) and 0.52 to 1 for large nations (USA, Japan, Germany, France, UK).

Until recently, industrial research received little government support; in 1973, private enterprise financed 97% of its R&D. A very significant increase in government funding for industrial R&D (Incentives Grant) in 1979 has not yet come into effect and still falls short of the level of many industrially stronger or comparable countries (Canada, France, Germany, Norway, UK, USA), where Government funds between 20% and 50% of industry's R&D.

Distribution of Workforce

Australia's distribution of employment over the main economic sectors (see Table 6, Statistical Appendix) is remarkably close to that of the USA and other developed nations. We thus reflect the pattern of evenly and fully developed industries; in this respect we are very different from developing countries.

Employment of Scientists and Engineers

However, Australia and Canada differ from the general pattern of employment of scientists and engineers in developed nations in that almost twice as many technical graduates are employed by Government (see Table 7, Statistical Appendix). The importance of manpower resource for smooth technology transfer and diffusion is mentioned below.

COSTS AND BENEFITS OF S&T IMPORT

There are four ways to acquire technology: licence (lump sum and/or royalty); attract investment; generate through local R&D; or do nothing; the latter is often a good option provided it is deliberately selective.

Visible Costs and Benefits

The visible costs of science support (scientific equipment, literature, travel) are trivial compared with benefits. One form of science transfer, CSIRO's and the universities' policy of appointing the best available man for the job from anywhere in the world and to provide attractive terms of appointment has been an unqualified success. It has sped up the process of developing local science immensely and is a precedent well worth recalling in the climate of emerging nationalism in developing countries. It is by no means a new phenomenon: The Doge of Venice attracted Galileo, Rudolf II appointed Tycho de Brahe and Kepler to his court and so created centres of excellence (alchemy!) and Peter I imported appropriate tradesmen to develop mining in Russia.

To the almost negligible cost of science import one might add the national expenditure on local science, particularly non-applied science, as our moral quasi-tribute in exchange for access to the international science pool.[10, p 30] This cost is entirely conceptual, but not small (about $430 million in 1973, 0.7% of GDP). More significant is that it has created a large resource of qualified technical staff on which industry can draw and which is of crucial value to rapid and smooth transfer and diffusion of imported technologies. In this sense it could also be considered as part of a manpower training program for technology import.

The financial analysis of technology import is highly complex and full of uncertainties. An UNCTAD Report[7] expresses concern at the relatively high proportion that payment for technology import represents in the national exchange of truly under-developed nations. The visible cost of technology import takes two forms, which can be considered interchangeable: royalty payment, or an undefinable proportion of profits which may be paid out as dividends or re-invested in Australian development. It is probably beyond the economists' skills, and certainly beyond mine, to present a national balance sheet of either and assign to it a proportion of the national know-how. Indeed, I would find it extremely difficult even for my own company. Nevertheless, a few simple statements and figures can be produced.

- Technology import concerns complex parcels of invention, innovation and the Boston experience curve, composed of many steps. In small countries and small companies the steps are frequently too few to coalesce into technology or the market is too small to reward the concentration of effort. Thus, in the vast majority of cases, technology import is by far the most economic method of acquiring know-how.

- The cost of know-how is only one component of launching a product; design, capital, testing and market development are at least as important. Consequently, these other factors may all be major contributors to either cost or foreign ownership.

- Obviously, there is no absolute preference for any one of the four development options. In particular, whether development by local capital is preferable to foreign investment depends on the terms; a 3% or 5% royalty with lower productivity can be more expensive than remission of dividends to an overseas company providing continuous know-how with higher productivity.

- Technology import by partial or full foreign investment and by licensing have been exercised successfully. The Japanese and Taiwanese economic take-offs were based on grand-scale licensing policies and their productivity has more than offset problems of foreign investment or licence burdens.

- The time factor usually favours technology import as local research is not always ready when the market is. Thus, for example, acquisition of chemical, textile and computer technology by licensing brought the Japanese to the take-off point more rapidly than indigenous R&D alone could have done. This is accentuated by inflation as cost and salary escalation ahead of the CPI favours import over drawn-out R&D, on a net present value basis.

- Australian statistics *prima facie* give the impression that our know-how bill is moderate, both as a fraction of GDP and of foreign exchange. Similar costs might be a greater burden in underdeveloped nations with little foreign exchange and lower gross domestic product.

The visible cost of royalties in Australia (Table 1) has declined to less than 0.15% of GDP. In the less developed countries it lies between 0.04% and 0.4% of GDP.

A different visible cost is the income payable overseas on direct investment in manufacturing. In 1974/75, these payments amounted to $A271 million which was 3.6 times the total royalty and copyright payments. The major part of this cost represents return on shareholders' investment, although in some cases it might contain a royalty component. No more than a small fraction of these payments could be arbitrarily allocated to know-how. Table 1 would indicate that the total 'visible' figure is now below 0.2% of GDP and below 0.75% of GDP in manufacturing. This can be compared with R&D costs, expressed as % of sales, for various industries: 0.1% to 1% for the food, steel and paper industries; 2.0% to 4% for chemicals and plastics; and 5.0% to 12% for pharmaceuticals and aerospace. It also can be compared with a national GERD in Australia of 1.2% of GDP.

It should, however, be borne in mind that international comparisons of figures such as these are not necessarily indicative of research capacity as research costs per unit vary considerably.

Know-how payments of the order of 0.75% to 1% on sales, less than 0.25% of the total GDP, and less than a quarter of GERD seem good value for money.

In the case of my own company, our research contribution to the parent company is taken into account in the balance. As a result, our royalty payment to ICI is less than one-eighth of the expenditure on our Australian R&D. Yet, there can be no doubt that the 'ICI family' know-how is the mainstream and that my own department's contribution in comparison with ICI's $280 million R&D expenditure is merely a small, but necessary, local component. In effect, we get the benefit of wider use of our research by ICI overseas and, in addition, we receive overseas royalties from third parties exceeding $1.5 million p.a.

Invisible Costs and Benefits

However, royalty statistics are merely the tip of the iceberg. The majority of know-how, particularly in wholly owned subsidiaries, flows by information exchange between associated companies as a true invisible and is absorbed in the reward to investment capital or prices. It is probably impossible to separate the reward to capital and to know-how. Nonetheless, a broad assessment of the cost of overseas investment to the host country can be attempted.

Table 2 shows that average return on shareholders funds for the chemical industry (ACIC members) over the decade 1967-1976 was 6.3% (ICI Australia 7.7%), compared with the average 20-year bond rate of 7.3% over the period. Assuming royalty payments were accounted for separately, the foreign investor in the chemical industry did not receive the long-term bond rate, despite the injection of know-how and the risk involved. Of course, the investor in bonds would have suffered a capital depreciation on the value of his bonds. However, the investor in a chemical plant in 1965 would likewise have found it impossible to replace that plant in 1976 with the 10% p.a. depreciation money that he had set aside each year. His only hope of a capital gain was that the plant had not become obsolete and was still a viable operation.

It would appear that to date the provision of overseas investment capital has not been costly to the host country. The savings in foreign exchange from import replacement must exceed outgoings many times. In the long term, structural effects may be far more significant.

TABLE 2

Average Return on Shareholders Funds

Year	20-Year Bond Rate*	ACIC Members % After Tax return on shareholders funds**	Net Profit available to ICI (Aust) $M	ICI(Aust) shareholders funds $M	ICI(Aust) % After Tax tax return on shareholders Funds***
1967	5.25	3.5	10.6	179.3	5.9
1968	5.25	3.6	13.1	182.9	7.2
1969	5.87	7.0	15.0	190.2	7.9
1970	6.99	5.9	15.8	192.7	8.2
1971	6.99	7.4	14.8	192.1	7.7
1972	5.99	5.6	15.2	185.7	8.2
1973	6.99	10.9	22.6	204.2	10.7
1974	9.49	6.6	22.2	276.5	8.0
1975	9.50	2.1	15.2	274.5	5.5
1976	10.20	10.1	21.1	276.0	7.6
Arithmetic Mean	7.3%	6.3%			7.7%

* June 30 years
** Calendar years, ex ACIC facts and figures
*** Sept 30 years, ex 48th Annual Report, 1976.

The linear sequential science to technology model (the social warrant for basic research)

The flow of economic benefits from basic science to technology is relevant to the choice between technology import and local R&D. In the first half of this century the pervasive optimism of 'today's science is tomorrow's technology' held out a simplistic promise of cause and effect. Later analyses, particularly by Rothschild,[12] argued that technology and science developed almost side by side, providing mutual stimulus. Differing studies have championed basic research[13] - science push - or technological target (applied) research[14] - market pull - as the mainspring of progress. 'There is now a growing discontent with linear, one factor polarised models of explanation.' This is reflected in recent, less polarised statements of the two positions: ASTEC[10, p 79] says; 'The history of technological innovation abounds with examples of practical applications and commercial developments which derive fairly directly from basic research. Most disciplines of science can offer examples of basic research which subsequently turned out to be useful. In many cases this happened even when the scientists concerned could not envisage any useful application, as Rutherford failed to see for atomic energy. Technological progress has often hinged on a complex web of interactions between basic and applied ... science.'

De Solla Price[15] presents the other end of the moderate spectrum: 'What came from the professional ranks, especially from the distinguished groups of science policy analysts at OECD and the Science Council of Canada, were the recognitions that innovation in industry had very much more to do with market pull than with technological availability push, and that there was a far from simple relationship between science and technology that emerged as we came to know more detail of their respective histories. In the history of science, technology enters frequently either as the provider of new opportunities to study by means of processes, substances and apparatus that had not before been available to excite the spirit of curiosity, or as a provider for interesting, Pasteur-like problems that start in industry and end in the scientific journals. In the history of technology on the other hand, even in cases that stand as mountain peaks, like the transistor, penicillin, the computer and the laser, once one knows how the advance was actually made it tends to follow more closely the nineteenth century aphorism of "thermodynamics owes more to the steam engine than ever the steam engine owed to thermodynamics". This must not be pushed into a flat statement of diametrical opposition to the traditional view of the 'application' of science, for that also would err as much in its simplicity. Perhaps the most appropriate image is to consider science both as a quintessential juice squeezed from technology and providing a nutritive fluid for further technology.'

In the case of Australia, and the developing nations, both views must, however, be seen in the context of scale.

Science and technology quanta - the 'coalescence phenomenon'

Science progresses in smaller quanta than technology. Although the science quantum jumps differ immensely in merit, each quantum, usually an idea or observation, is communicable separately between individuals with the barest of references and irrespective of proprietary rights. The quantum cost is low, often trivial.

New technology, by contrast, involves the recombination of masses of quanta from the art, including some critical new steps which are usually patented. It depends on market needs and is incomplete without full-scale demonstration and establishment in the market. It involves massive, coordinated, interdisciplinary teamwork, cost, documentation[2, p 97, 217, 219], and proprietary rights.

To become economically useful, S&T quanta must coalesce into a new body or grow onto an existing technology and the whole of the coalescence process must occur within a critical time and area. The point that has not emerged clearly in the science/technology model debate is that random innovation quanta in a particular area, in a small country, are insufficient to form a technology. Hence S&T coalescence occurs much less readily in small than in major industrial territories. Unless there is selectivity and concentration in R&D, as for example in Switzerland, the minor countries' contributions to science are not reflected in proportional yields in technology. Their science droplets tend to coalesce where the major science pools are - overseas, as evidenced by the fact that 84% of the world's inventions are made by Germany, France, Switzerland, UK and USA.[7]

The scale phenomena are better understood in relation to the individual firm. The Boston Group have shown by their 'experience curve' that for remarkably many and different processes and products, costs decrease by roughly 20% with each progressive doubling of output - the collective improvements constitute technological superiority.

The Boston curve is a key factor in technological advances. The competitive ratio, that is your size, compared with your biggest competitor in the field, in terms of cumulative tons output or R&D man-years, is critical. Minimum viable plant scale is well understood. Inadequate scale makes a high proportion of projects unacceptable in small markets. The rate of technological development, often requiring hundreds of man-years, is equally critical since slow development virtually amounts to losing the invention to competitors. Since science is international, random science import will accentuate orientation towards overseas advances and fashions. A highly fragmented science mosaic will result, with virtually all trends being reflected and linked to peers overseas. If, then, the pieces of the mosaic within a small country are too few to create or feed a technology, the science to technology link does not close.

The Australian R&D bill for 1973 was $A666 million. If there were a wastage of only 10% of scientific results by an imbalance between research and its utilisation, the cost of this imbalance between science and technology would equal the total nett royalty outflow for technology import. Few would deny that the proportion of unutilised Australian R&D is substantial. The urgent need to increase the level of industrial R&D and the lack of 'experimental development'[10, p 1, 3] have been recognised. Australia's science is inadequately oriented to and/or inadequately matched by its industrial R&D.

The science/technology coexistence

The less than linear sequential relationship between technology and science, particularly within our small economy, has already been referred to. Interaction has been excellent in the geographically-bound fields, agriculture and mining. However, unfortunately, neither of these is particularly research intensive. In addition, terms of trade in agriculture have deteriorated steadily. The modern manufacturing sector,[7] however, has received little attention, virtually as a matter of policy, since so much of Australian research has been centred in government establishments without access to manufacture and without access to international proprietary know-how. The technologist. on the other hand, often could not justify local research for a small market. He could, however, import packaged and established know-how from overseas. In broad outline, Australian manufacturing industry, through technology import, successfully built up a highly diversified, balanced industry, based on import replacement. Largely independent of industrial development the Government, CSIRO and the universities built a strong, likewise highly diversified network of centres of excellence.

Thus, both scientists and technologists became locked into separate matrices. Scientists looked to agriculture, overseas trends and peers and technologists to their international companies or licensors. Technically, this was closer to coexistence than to symbiotic interdependence. Many scientists turned away from application and manufacture. This explains, in part, the overemphasis on the more esoteric fields. The areas which are most research sensitive (electronics, communication, chemicals, drugs, and engineering) do not rank high on the national R&D bill. The lost opportunity for industry and R&D is the major hidden cost. In the period of industrial emancipation, this mattered less. The first task was to build industries and to create a strong scientific force - in manpower and reputation. Now that both tasks are completed, some structural problems have emerged.

Both industry and science are highly fragmented. Outside mining and a handful of industrial laboratories, there are few if any areas of concentration providing a research power base for industry. Having grown rapidly, ahead of the GDP, to displace most imports, the research-intensive, high growth industries are now slowing down towards GDP growth rate. Most derivative technologies, encumbered by high labour, capital and transport costs and without special technical advantages, have little prospect of growth by export. Researchers, with strong basic and local orientation, have not faced the fact that most R&D can only pay for itself and compete with other R&D if it is oriented to, and exploited on, large markets internationally. Many industrialists, having grown up in an atmosphere of quick and competent technology import, have not yet learnt to rely confidently and patiently on research as the road to special advantages and markets. Few manufacturers treat R&D as a fully integrated component in the manufacturing chain, as overseas manufacturers have done traditionally.

This may seem a somewhat gloomy picture. It is not; it is merely a phenomenon of change. Even with hindsight, Australia could hardly have done much better since World War II than rapidly industrialise by technology import, strengthen her agriculture and at the same time build an impressive scientific resource by Government initiative.

The wishful corrections by hindsight, namely greater selectivity and concentration in some industries, particularly in high added value/growth/skill industries, have emerged clearly as an urgent need only now as the import replacement phase has closed. Yet import replacement will remain a good bread-and-butter strategy; hence we can only hope for progressive upgrading of our technical strength by selection in some areas.

Two great benefits remain from the input replacement phase established modern industries with full access to the most up-to-date technology of leading international companies and a highly competent, scientific manpower. To be fully effective, these resources need to be linked. This is a major concern of ASTEC,[10] Birch[16] and also bears upon UNCTAD's report.[7]

CONSTRAINTS IMPOSED BY TECHNOLOGY EXPORTERS

Overseas Know-how and Local R&D Skills

The Australian chemical industry has considerable experience in integrating local and overseas know-how; there remains, however, wide scope for fuller interaction with the local public sector. There are few published reports of the integration of Australian industrial R&D; one of these[18] is an account of ICI Australia's case histories. ICI Australia built the Botany petrochemicals complex by importing the olefines, polythene and PVC technologies from the parent company, and buying ethylene oxide know-how from Scientific Design. However, the (then) new vinyl chloride/oxychlorination process and the bulk of the ethylene oxide derivatives, including brake fluids, were developed in the Australian laboratories. Only by combination of technology import and research could the timing and optimisation be achieved. Local research was successful largely because it stood on the shoulders of international know-how.

Selectivity is considered important. The company concentrates R&D in sectors of local need, like explosives or the PVC process. ICI Australia also operates one of the two ICI animal health research centres aimed at the international veterinary drug market. The centre operates across the full research spectrum, from synthesis to evaluation and ICI Australia shares in financial benefits derived on overseas markets. Without the link to ICI overseas and without pre-existing overseas marketing and specialist support, for example, in toxicology, exploitation of the Australian work overseas would be far more difficult.

No doubt there are many other methods of sharing in research benefits internationally by coordination. ICI's policy of progressive decentralisation of R&D, practised for more than two decades and combined with local management and local shareholding, has established one equitable and symbiotic system.

However, the resources of any one industrial laboratory in Australia are limited and thinly spread. Government research, on the other hand, often operates outside international know-how and outside the major targets of industry. Whilst collaborative efforts between manufacturing industry and Government, such as 'Interscan', and 'Sirotherm', have been carried out, their overall economic impact has remained small. Efforts need to be broadened and mainly concentrated in industry's innovation-sensitive 'core' areas. Research is not a zero sum game; all parties can win. It should not be beyond the imagination of administrators to devise agreement structures which will secure equitable sharing of benefits amongst the public sector, local industry and the overseas owners of the basic knowhow.

Industry has already accepted the concept of such cooperative arrangements. The government White Paper[17] implies some restructuring of industry towards high skill industries. Selective concentration of R&D in research-intensive areas is a relatively painless method of restructuring and is much less costly than divestment of whole industries. Government collaboration with local R&D also encourages decentralisation of research by international companies. Without some compromise in integration with international industrial R&D the bulk of public sector research will remain isolated from international know-how and the local private sector will lack the resources for major innovation. Australia and Canada are fairly unique in this situation and will need to pioneer solutions.

Tied Purchases

Most tied purchases among non-related (less than 50% common shareholding) companies offend against Australian Trade Practices legislation. Among related companies there may be 'most favoured supplier' clauses which are limited to preference, all other things being equal. This does not appear to be objectionable.

Local experience is that negotiations between associates, where the parent company has to match competitive offers and grades, are conducted at arm's length. If anything, negotiations are sharpened by the insight into the parent company's business. However, technical insight and commercial skill are prerequisites. Free buying is the prevailing practice. However, the need for standardised specifications of supplies is frequently a source of misunderstanding in less developed countries. Specifications are often critical and usually justified, but may not be clear to the recipient. This and other constraints imposed by the needs of technology are well displayed in Bradbury.[2]

Export Restrictions

Export restrictions by some licensors have been reported. Amongst non-related companies they may offend against Australian and overseas (US) Trade Practices legislation, as territorial limitations. They may, however, be justified in relation to patented products. Most research-intensive organisations, whose ability to do research depends largely on the patent system, would dissociate themselves from the arguments against patent rights presented by UNCTAD[7, p 35-37]. If these arguments were accepted, they would rescind one of the most effective tools through which small organisations and small countries can build up their industrial strength.

The real problem with exporting licensed know-how is often that the licensed product has long been established in overseas markets on a large scale before it reaches Australia or a developing country. With the disadvantages of scale, time and transport, it is then hard to catch up. Hence the need to do local research to improve the product or to invent something else.

Limitation on Diffusion of Purchased Know-how

The argument has been advanced[7, p 24] that know-how, once licensed to one organisation in a country, should be automatically transferable (sub-licensable) to others in that country. Likewise, it has been argued[2, p 78] that technology should be transferred at the marginal cost of transfer once the development cost has been amortised. Both concepts appear to treat know-how as an article paid for and disposed of once and for all.

Commercial research-based organisations, on the other hand, consider that royalties should be related to volume and hence reserve the option to optimise volume by exclusive or non-exclusive licensing. Furthermore, royalties for past discoveries should not only recoup past expenses but, if their commercial value justifies it, should support current and future research, the failures as well as successes. Both concepts appear to be acceptable and understood in Australia. The higher the research component is in the cost structure of a product, the more they are justified. In some of the most spectacular technological developments, from drugs to computer, research is the predominant cost. To base their value on raw material costs, after the discovery, and reward it accordingly is to 'kill the goose that laid the golden egg'. This is not to say, that such costs may not be beyond the capacity of an emerging nation. The solution to that problem, however, is a matter of international solidarity and other forms of support.

CONCLUSION

Overviewing some of the key costs and benefits of Australia's liberal blend of science and technology import, one is led to the conclusion that it has been a fairly successful recipe. No doubt it has been greatly helped by a fortunate combination of national characteristics, natural resources and a liberal tradition. The end result would tend to encourage others to pursue similar liberal policies. At the same time, at the close of the import replacement phase, the resulting structure has left Australia with some significant problems of reorientation. These may be an early warning to others to build a measure of specialisation into their growth pattern.

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WORKSHOP DISCUSSION

TRANSFER OF INTERNAL AND IMPORTED SCIENCE AND TECHNOLOGY WITHIN AUSTRALIA

REPORTER

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1. INTRODUCTION

The syndicate regarded technology as any specifiable, definable way of doing something, and understood the concept of technology transfer to involve the generation, development, diffusion, adaptation and application of technology. We were thus immediately concerned with those who create, adapt and use technology, and with the processes by which scientific developments evolve into processes which are useful for some purpose.

The syndicate confined itself to the transfer of existing technology and not to defining appropriate technology, that is, those technologies which benefit mankind, or any of the other matters which were primary concerns of other syndicates.

2. THE NEED FOR NEW TECHNOLOGY

It is difficult to envisage a scenario in which new technology will not play a part in the future welfare of Australia because:

(1) technology is the only answer to shortage of raw materials and energy;

(2) technology will be important if Australia's standard of living is to be at least maintained relative to that of other countries;

(3) technology will allow substitution of alternative products, even in a situation of declining growth in the Australian economy; and

(4) technology is needed to maintain defence preparedness.

The syndicate recognised that Australia's development is interdependent with that of other countries and that decisions relating to science and technology must be made with this interdependence in mind. But technology is itself an important factor in our economic competitiveness with other countries.

3. THE DEVELOPMENT OF AUSTRALIAN SCIENCE AND TECHNOLOGY SINCE WORLD WAR II

The war created many benefits for Australian technology, including industries and nuclei of industries created by the war effort. The war also exposed gaps in our industrial capability which were swiftly closed afterwards, either by import of technology (eg tin plate) or by import substitution (eg newsprint).

A conscious effort was made by Government to develop local manufacturing capability. Why? Manufacturing provided important avenues of employment for Australians affected by the world-wide trend of reduced demand for labour in agriculture. Manufacturing was both supportive of and supported by the immigration program.

These factors made the government policy of replacing imports with locally produced goods relevant and sensible.

At the same time primary industry was the big earner of foreign currency and it therefore made sense to put a lot of technological effort into it.

In the post-war period, the receptivity of Australia to technological innovation was improved by:

(1) introduction of techniques through industrial laboratories;

(2) a big CSIRO effort to import instrumentation and modern techniques, as well as scientists;

(3) isolated efforts by other government research institutions and a few large companies to import excellent scientists;

(4) development of local talent, particularly in the explosion of post-graduate science education.

There was also some export of expertise by feedback and licensing. It must be admitted, however, that the import of excellent scientists has not generated an equally impressive output of excellent technology.

In agriculture, Australia has identified its needs and concentrated its scientific effort, but there was consensus that:

(1) in aggregate, Australian technology has been overwhelmingly derived from overseas - estimates in the syndicate ran as high as 95%. It was also agreed that this was not a cause for alarm in view of Australia's population relative to that of the rest of the world, and in view of the fact that all countries import technology (a figure of 60% for the US has been cited);

(2) the 'science push' has characterised public sector research and that this was perfectly proper in fostering the growth of Australian science to the state of maturity which has now been attained;

(3) import replacement was becoming less a driving force in the Australian economy; and

(4) the coincidence of Australia's scientific maturity and the end of industry's import replacement phase meant that 'market pull' now had to be given much greater priority in the direction and development of Australia's government research effort.

4. RELEVANCE TO TECHNOLOGY GENERATION OF THE POST-WAR AUSTRALIAN SCIENTIFIC EFFORT

The Public Sector

Over several decades, CSIRO's effort was concentrated in the resource industries, particularly agriculture and mining, which derived major and lasting benefits from this work. Related industries (food, wool and cotton processing, forest industries, housing) also received strong support from CSIRO. Across the spectrum, industry benefited from productivity improvements (technical advice, adaptation, discovery and diffusion of new techniques).

On balance however, research in CSIRO and universities was characterised by 'science push' - basic orientation and the publication race - rather than orientation to the needs of manufacturing industry and its markets. Little effort was made at concentration in this sector as a whole, or in selected parts of it. As a result such benefits as the manufacturing industry, and particularly the fast-growth/ high-skill industries, derived from public sector research were not a significant factor in their development.

The Defence Science and Technology Organisation (DSTO), TELECOM and the Australian Atomic Energy Commission (AAEC) fulfilled special functions which considerably limited the spin-off to industry from their work. The benefits derived by Australian industry were much less significant than the benefits industry in larger countries derived from similar organisations.

Two major resultant defects in the Australian R&D structure are:

- the virtual absence (or at best insignificance) of government contract R&D, and
- the low degree of experimental development.

The Private Sector

Industrial research is relatively weak in the private sector; in the recent period of reduced employment in industry it has declined further, to about one fifth of the national R&D effort. From now on, significant support should be derived from the Federal Government's IR&D Incentives Grants Scheme.

The bulk of industry's work is applied; it relates to productivity development, to adaptation of imported technologies and to new processes and products. A number of Australian plants and products, as well as export of products and know-how, are based on this work.

5. UNDERSTANDING THE PRESENT

The condition of science and technology in Australia is under scrutiny. Many inquiries have been made, others are in progress, and no doubt there will be many more in the future. The syndicate was a little inclined to think that 'if words were bread rolls there would be no problem'. At the same time, we recognised that the inquiries, and the creation of permanent bodies such as ASTEC, were healthy signs of recognition of the shortcomings in the present system. So was the allocation to executive departments, such as the Department of Productivity, of new responsibilities in matters such as technology assessment and technology transfer. Most members of the syndicate, however, had some difficulty in accepting so exotic a concept as 'the bureaucrat as catalyst' in technology transfer.

The syndicate accepted the proposition that science has no social responsibility but technology has. This is not to say that fundamental work in science is not important to society. Many examples were produced of work begun out of purely scientific interest which later proved to be highly relevant to technological problems.

It was pointed out that every bit of imported technology which used a biological or mineral raw material had to be adapted. While the bulk of such adaptation of imported technology is done in industry in Australia, the importance of fundamental scientific understanding in such adaptation was stressed. The need for adaptation of so much of technology has, of course, also to be appreciated in attempts to export Australian technology.

In discussing the relationships of the universities to industry, the syndicate was firmly of the opinion that universities should not have to justify their existence in terms of their contribution to industry. It was acknowledged that some sectors of Australian industry had suggested that students had not always been trained in those scientific areas which were most relevant to industry. However, the consensus in the syndicate was that it was basic scientific education rather than particular subject knowledge which was important. There was some feeling, however, that universities could do more to condition students to see employment in industry as a fulfilment of their scientific training.

The major problem seen in technology transfer in Australia today is the gap which exists between government research, which is not informed of the needs of industry and is unappreciative of the forces of 'market pull', and industry, which is short of scientifically trained receptors of ideas and lacks appreciation of what benefit it could get from scientific research. It was noted that the difficulties in getting government research applied in industry were different in degree, rather than in kind, from the struggles within companies between R&D departments pressing for innovations and management preoccupied with selling the products currently made.

The responsibility of government science for the development and proving of its own new technology seemed to be accepted, with the proviso that interesting but uneconomic experiments ought to be ruthlessly laid aside. The syndicate stressed the importance of patents in inducing industry to use government research by providing attractive licensing arrangements. If, however, government policy insisted that government research organisations called for tenders from potential licensees for new processes, there were dangers of disclosure and consequent disadvantage. The syndicate welcomed the recent signs that the Australian Patent Office was beginning to take much greater interest in the diffusion of patent information through its Australian Patent Information Service (APIS).

6. THE FUTURE

Can changes be made in Australia which will lead to more effective technology transfer? Mindful that these are matters in ASTEC's purview and which are also no doubt of concern to the Inquiry into Technological Change, the syndicate would, even at the risk of redundancy, like to offer the following recommendations.

(1) Mobility

The syndicate strongly endorses ASTEC's call for further study of the mobility of scientists and technologists in Australia.

Private initiatives for exchange between government research institutions, universities and industry should also be encouraged.

(2) Receptivity

Greater mobility would assist in the creation of people in all sectors who are more aware of the possibilities and problems in the whole science and technology system.

The syndicate recommends government and industry cooperation in the creation and strengthening of research associations, and in the use of representatives of industry on advisory committees in government research organisations.

Only by closer association and increased mutual trust will government science and technology be able to assist industry in the identification of its needs.

(3) Selectivity

Small nations must concentrate their effort if they are to have technological impact.

The syndicate recommends that much more of Australia's R&D effort ought to be directed towards high-yield areas selected on the criteria of:

(a) the existing power base of scientific knowledge,
(b) national needs, and
(c) national opportunities.

The syndicate stresses that contributions to decisions on the selection of R&D areas should be made, and be seen to be made, by all the parties involved.

(4) Development

The gap between discovery of technologies and their application in Australian industry ought to be of concern to both Government and industry.

The syndicate recommends that initiatives towards the creation of an Australian research and development corporation be pursued energetically.

(5) UNCSTD

The syndicate urges the UNCSTD delegation to take to Vienna an appreciation that the transfer of technology, whether within or among countries, is a complex problem.

There are no mechanistic solutions, but Australia could adopt an organic approach which would allow much better use of technology for the social and economic benefit of its people and those of the rest of the world.

TRANSNATIONAL MOVEMENT OF SCIENCE AND TECHNOLOGY - A CASE HISTORY

BY

H.L. VAN VUGT

Mr Van Vugt was born in 1934 in Indonesia, moved to Europe in 1946, and was educated in the Netherlands and England. He started work in 1955 in South Africa.

Mr Van Vugt was invited to join Repco in Australia in 1960 and spent much of the first six years overseas contributing to the company's export drive. In 1967 he was appointed General Manager of the company's clutch manufacturing company.

Currently, as Divisional General Manager, Mr Van Vugt is responsible for 13 individual manufacturing companies, three of which are overseas, and serves on the Boards of the latter, representing Repco Limited's interests.

When, shortly after World War II, the Australian Government invited General Motors to invest capital and technology in Australia to manufacture a motor car, it attracted in its wake a host of automotive component manufacturing enterprises. The latter consisted of both foreign and Australian manufacturing companies.

The Repco Universal Joint Company, a wholly owned subsidiary of Repco Limited, which is an Australian-owned public company, was set up. Technology was imported in the form of a manufacturing licence from the USA. The prime purpose was to manufacture propeller shafts for supply as original equipment to General Motors and the company still does to this day.

The replacement business of propeller shafts is that of universal joint kits. In addition to developing the spares market in Australia, the company, with the aid of export incentives, also developed a viable export market.

The universal joint kit consists of a forged cross with four trunnions. After forging, the cross is heat treated to remove stresses, the trunnions machined, grease galleries drilled through the entire cross, and the unit then case hardened and ground to extremely fine tolerances of hardness, surface finish and dimensional detail. Four needle roller bearings are fitted to the trunnions, which, when fitted to the propeller shaft, are held in place by spring steel circlips of extremely close tolerances. The bearings are cold formed from alloy steel, case hardened and ground to extremely close tolerances. Dimensionally, most vehicles use different sized universal joints. It is the knowledge of these dimensions and applications which allows a manufacturer to rationalise his production and use a minimum number of diameters of bearing steel and cross forgings, which, through additional machining, can be made to fit another application. This is where the cost of additional material and machining must be carefully weighed against the additional cost of tooling and/or stock holding of bearing steel, the size of the market, and the ruling market price of the end product.

Dimensionally, universal joint kits can vary in size from approximately 40 millimetres to 1000 millimetres swing diameter (the diameter of the circle described by a complete turn of the unit). Normally, however, high volume production techniques are only applied to universal joints of up to approximately 250 millimetres swing diameter. Larger universal joints are used in very low volumes in steel mills and other heavy industrial applications. Once a universal joint is worn it cannot be repaired and must be completely replaced. The life span is entirely dependent on the application, driving habits, road and dust conditions and temperature. Thus, different areas of the world, and in fact even different areas in Australia, have widely varying replacement characteristics. The know-how of these conditions, which dictate the volume per part number and therefore the manufacturing techniques to be used for each part number, takes decades to develop and constitutes a technology in its own right.

For commercial reasons, material specifications, dimensional data and details of the manufacturing processes and conditions will not be published in this paper. As the particular types of technology applied to the manufacture of universal joints cannot be patented, but consist of technological know-how gathered over many years, publication of any or part of these technologies would be bad commercial practice. However, as the main purpose is to deal with the commercial and organisational aspects of the transfer of technology, it is hoped that the absence of detailed technical specifications will not detrimentally affect the paper's contents.

Escalating costs due to increased labour costs, unreliable deliveries due to industrial unrest and the elimination of viable export incentives caused the company to lose all its export markets. It is important to recognise that the loss of export markets resulted, among other things, in the loss of Australian jobs. Thus, in seeking to manufacture overseas to recover these markets the company was not faced with the prospect of exporting jobs since they no longer existed.

The company carried out a detailed feasibility study which showed that, in a country with a lower cost structure, we could manufacture universal joint kits and match the prices of our main competitors on the export markets. Subsequently, the author, together with his Executive Assistant, travelled through those South East Asian countries which were interested in attracting industry. Detailed discussions were held with government officials, bankers, and business men to evaluate which particular country had the most suitable characteristics for this particular type of industry. These characteristics consisted of geography, government policies, availability of suitably educated labour, transport efficiency, reliability and availability of power, extent of industrial infrastructure, and political stability. The government policies which were mainly of interest were those concerning foreign equity, tax and/or export incentives and repatriation of profits.

The discussions with government officials of most countries (Singapore is most certainly an exception) showed up what I consider to be the biggest impediment to the success of the transfer of science and technology to developing countries. Many of them were totally ignorant of technology-based manufacturing industry and its ramifications. Usually these were the same people who made the rules and/or shaped government decisions.

The nature of research and engineering development was rarely understood and there was certainly no understanding of the costs involved. Royalties to be transferred to the parent company to pay for the cost of engineering development was regarded with suspicion. The strategic importance of retaining control through equity, or other means, of a manufacturing enterprise which was going to produce the same products as the parent company was, in most cases, not accepted.

It became rather obvious that most rules and regulations were based on manufacturing industries which did not require appreciable investment in research and development. In fact, many negotiations indicated that the thinking was based on the concept that offering access to cheap labour was the most important factor of all and that they were doing a favour making it available. The importance of transport and communication efficiency, reliability of power and a sufficient industrial infrastructure were not understood. The potential damage to fully automated hot forming lines with induction heating elements and automatic vacuum sealed quench heat treatment facilities through power failures was not understood.

The debilitating effect of unreliable transport facilities on a multi-million dollar fixed investment was certainly not appreciated. In some countries which are well known to have considerable 'graft' problems, the efficient operation of a capital-intensive manufacturing industry would be an extremely risky proposition as the lack of certain fairly critical materials could cost that company huge sums of money. My discussions with expatriates in charge of manufacturing companies in such countries, the details of which, for obvious reasons, I cannot publish in this paper, clearly indicated to me that the problems were of such a nature that the additional costs to the operation would far outweigh the benefits to be gained. The result would be that while the enterprise might possibly be a financial proposition if it were only reliant on such a country's domestic market, the company would not be able to compete on international markets. This in turn would make the investment much more vulnerable to local conditions and again increase the risk factor. Repatriation of royalties and/or profits would also present complications.

Regional grouping in the ASEAN area is in its infancy and this also presents a problem. There is no doubt that at some time in the future economic and/or political blocs will evolve and no doubt these blocs will rationalise their capital-intensive production facilities. However, any potential investor who bases his projections on government statements at this point in time can come unstuck. A very good example is a plant in the Philippines built by a large American organisation which was based on certain projections for local content. The level of local content required in this particular case was never formally gazetted, which resulted in the company concerned pulling out without manufacturing one item. In addition, it left in its wake a number of overseas investors who had set up factories to supply it with semi-finished raw materials.

The above observations presume that, in a mixed economy, a very large percentage of science and technology is transferred for financial gain. Therefore, all considerations revolve on financial efficiency of the transferee and the effects on the transferor. The benefits to the host country's economy are only realised if the plant is financially and economically efficient. Therefore, it was a very discouraging experience to try to discuss the requirements of a capital-intensive industry, involving sophisticated technology and making enormous demands on human and financial resources, with high-placed officials who had a total lack of understanding of these factors. I firmly believe that if the transfer of science and technology is to succeed and benefit the standard of living of the people of some of those countries, the officials who make the decisions on such projects should be educated accordingly. This could easily be achieved by the developed countries' Governments approaching the developing countries' Governments with a view to designing a scheme for this particular purpose.

The above criticism of a certain lack of understanding encountered in some countries is in no way intended to be patronising - it is meant to be constructive. It must be borne in mind that these conditions were encountered during the well-planned and realistic efforts of a large organisation willing to invest many millions of dollars to establish a highly sophisticated manufacturing industry.

Most countries did not differentiate between a technology-based industry and the simpler, more labour-intensive, industries. Also surprising was that most Governments only allowed a short period of foreign equity before it had to be diluted to a minority holding. It is an accepted fact that when establishing a technologically based industry, one normally sustains hefty losses for one or two years. Therefore less than 100% equity in that period is not particularly attractive. To be forced to dilute that equity once the industry becomes viable further postpones the pay-back period and thereby increases the risk factor.

Many countries did not recognise that a technology-based industry generally is not portable. The buildings usually have to be designed around the manufacturing equipment and processes and become almost worthless if the project has to be abandoned. In addition, some of the manufacturing equipment costs almost as much to shift and reinstall as to buy new. The entire complex becomes almost unsaleable, which adds significantly to the risk factor.

I am sure these factors would be completely different with simple processes and/or assembly industries which in the main use light, reasonably portable equipment and some jigs and fixtures. In these industries no significant technology is invested as they are much more labour orientated and control of the equity is not as important.

Some countries have set aside areas where expatriate enterprises can own 100% equity provided the industry exports most of its production. However, in most instances, these areas are fairly remote, and lack three very necessary attributes: an industrial infra-structure, efficient transport, and reliable power and communication.

Finally, taking all factors into consideration, Singapore was chosen as our host country. The factory building has been completed, the equipment ordered, and the company should be in production during the second quarter of 1979.

The technologies which are being transferred cover engineering-design technology, manufacturing technology, and product know-how, which consists of dimensional data, applications, part numbers and volumes and combinations of these factors. These three categories have been built up over some 30 years and represent a very heavy investment. To transfer all this technology we could send some 20 experts from Australia to Singapore to gradually pass on the information and then return home after a number of years. Alternatively, we could try to search out Singaporeans with the necessary educational background, experience and mental attitude for training in Australia.

The first alternative was unacceptable on two counts: we could not spare such a number of our experts from our home factories for such a long period, and the cost of keeping expatriates in Singapore would be too high.

It was decided that only the General Manager and the Manufacturing Manager, both naturally thoroughly conversant with the management and manufacture of universal joint kits, would be sent from Australia. We then instructed an executive search bureau in Singapore to seek applications for the following positions: Quality Control Manager, Chief Engineer, Plant Manager, Industrial Engineer, Purchasing Manager, Personnel Manager, Finance Controller, Metallurgist, and Production Supervisors for heat treatment, machining and grinding, and hot and cold forming. A short list was compiled and the General Manager and I flew to Singapore to carry out the final interviews and select the appointees. Each one, with the exception of the Purchasing and Personnel Managers, spent from 2 to 12 months in our Melbourne factories, the length of time depending on the complexity of the technology to be absorbed and the education and experience of the man involved. However, certain types of technology are so complex that the manufacturers send their own experts to install and commission the equipment. The contract stipulates quite clearly that it is the responsibility of the equipment manufacturer to get satisfactory production from the machine before the final payment is made. The processes I am referring to are those of hot forming and cold forming. The hot forming production line is a fully automated line from Germany which crops, induction heats, forms and trims and requires only one operator, compared with 12 operators for the normal manual line. This equipment costs $A1.5 million and a special building to house both it and the cold forming line had to be designed. During its delivery and commissioning one of our own experts from Melbourne will be present for 3 to 6 months. However, to eliminate the risk of holding up total production, some ready-made forgings have been imported from Australia. As the equipment has capacity well in excess of our own forging requirements, it will also be used to manufacture forgings on a contract basis for supply to industry in Singapore and overseas. This is being done at the request of the Singapore Government as there is no forging industry in Singapore. Pioneer status has been awarded to us for the forging industry as well as for the universal joints industry. This means that we will not have to pay tax on profits from either of these enterprises for the first eight years. The additional production volume of forgings which will result made the installation of this extremely efficient type of equipment feasible. At lower production volumes only the simpler, smaller production capacity type of equipment would have been warranted.

The cold forming production line, which is also fully automated, was purchased from Japan. Again, because of the investment involved (close to $A1 million), the contract and the commissioning will be carried out on the same basis as for the hot form line. Again, one of our experts will be present for the first three to six months. For heat treatment, which is a power-intensive operation, the latest technology of vacuum heat treatment was selected as it has the lowest heat loss factor and with rising energy costs it represents a good investment. The metallurgist, who, as a matter of interest, obtained his degree at a German university, spent some three months in our plants in Melbourne and will spend a further two months in the USA actually operating the equipment under the manufacturer's supervision before it is shipped to Singapore.

Table 1 sets out the essential points behind the decision to purchase vacuum furnace heat treatment equipment.

TABLE 1

FURNACE COMPARISON

	Atmosphere furnace	Vacuum furnace
Electricity - rating	120 KVA	120 KVA (efficiency higher)
Caburizing gas (propane)	800 cu.ft/ht	50 cu.ft
Nitrogen - per heat	-	700 cu.ft
Carb. cycle time	8-12 hours	4-5 hours
Average load	1000 lb	1000 lb
Elements	Alloy steel (tough)	Graphite (brittle)
Explosion danger	High	Nil
Cooling water	Yes =	Yes
Cycle controls	Yes =	Yes
Gas generator	Needed + power	None
Dew point control	Needed	None
Thermocouples	Needed	Yes
Air	Needed	Yes
Max. op. temp.	1000°C	1300°C
Maintenance	Care required	Greater care required
Work loading	Care required	Greater care required
Product quality	-	Higher - due to degassing of steel surface
Furnace design	Hot wall	Cold wall
Pollution problems	Considerable	Negligible
Operation	Continuous for both furnace and generator	Batch - cold start for each batch

The acquisition of vacuum furnaces for the Singapore plant will provide Repco with the most modern heat treatment technology in the world and place us well ahead of our international competitors. In addition, by purchasing a 24-cubic-foot furnace and a 9-cubic-foot furnace, both with quench facilities, we have provided a safeguard against breakdown or maintenance stoppage as either furnace is capable of performing identical heat treatment processes.

The foregoing illustrates the two-way benefit of the transfer of technology. In our endeavour to obtain the very latest equipment for the factory in Singapore, we sent our top experts to machine tool and other manufacturers with whom we enjoy mutual associations in the USA, Germany, UK, France, and Japan. Each engineer is an expert in his own field and they all came back with extremely valuable information which is now being put to use in our plants in Melbourne.

In summary, we have achieved the transfer of product technology, manufacturing technology, and product know-how from our Melbourne-based executives to our Singapore-based executives. In addition, we have achieved the transfer of manufacturing technology from the German hot forming equipment manufacturer, the Japanese cold forming manufacturer, and the American vacuum heat treatment manufacturer to our Singapore executives. Management techniques also make up an extremely important and integral part of this technology. It can therefore be said that the interaction of all this information ensures that the whole is greater than the sum of its parts. It was achieved through commercial necessity and the dovetailing of the requirements of this particular manufacturing enterprise with those of the host country.

THE TRANSFER OF SCIENCE AND TECHNOLOGY TO DEVELOPING COUNTRIES: SOME ADMINISTRATIVE AND SOCIAL IMPLICATIONS

BY

A.F. GURNETT-SMITH

Mr Gurnett-Smith is Officer-in-Charge of the Centre for International Research Cooperation, established recently by CSIRO to coordinate its activities in scientific development assistance. He is also a member of the governing board of the International Rice Research Institute in the Philippines.

Prior to these activities he was Officer-in-Charge of the Centre for Animal Research and Development at Bogor in Indonesia.

His long-term interests have concentrated on research administration and the application of research results, especially in the rural industries.

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INTRODUCTION

I suspect technology has been transferred as long as man has been homo sapiens. No doubt defending his territory provided a strong stimulus to grab the latest idea from opposing tribes, even if his resources were strained in doing so. Hunger and environmental discomfort were important also. These motivations are well to the fore today.

As society became more complex new motivations emerged. For example, we see a religious motivation when King Solomon had technological problems in building his temple in Jerusalem. He asked his friend King Hiram of Tyre for 'a skilled craftsman able to work in gold and silver, copper and iron'. An all-round metallurgist you might say! But Solomon also wanted the 'metallurgist' to be expert in dyeing fabric and engraving. The man must have found himself in the same situation as most 'experts' on aid projects in developing countries today - he was expected to know everything about everything. But he had one thing in his favour. Solomon promised to provide the workmen he needed, so he had highly responsive counterparts - something not always experienced today.

History records other motivations for technological transfer. The city states of Venice and Genoa benefited from imported technology, with trade being a strong stimulus. In the 17th century the Huguenots, after being driven from France, took their weaving skills to England and so transformed it into the leading textile country in Europe. In turn this contributed to the general industrial development of England and even had a bearing on English dominance over France in North America. More recently, defence and politics led Japan to open its doors to the outside world's scientific and technological skills. Keenleyside[1] reports that over 5000 foreign experts were employed in Japan towards the end of the last century.

These examples demonstrate that, when motivating forces are sufficiently strong to prompt a vigorous search, the transfer and acceptance of science and technology are almost inevitable. Modern examples include Singapore, South Korea, and Taiwan.

SUBJECT MATTER AND MOTIVATION

While, for various social, defensive and commercial reasons, people with technology are prepared to provide it to those who actively seek it, they also attempt for similar reasons to coerce recipients who apparently do not have a clear understanding of what they need. The technology offered often outstrips peoples' ability to apply it. This imbalance can lead to confused thinking and frustration by both the recipient and the donor. Herein lies a major problem in technology transfer.

Ramalingaswami[2] referred to attempts over 35 years to reduce the incidence of disease in rural villages in India. While sufficient preventative, and indeed curative, technology to eliminate many disorders has been known for years, only limited progress has been made. A cheap and easily administered dose of Vitamin A would prevent night blindness, but thousands of children remain afflicted. Measles vaccines remain unused in many places. What is the bottleneck? Why attempt to export science and technology if it is not accepted?

In spite of many warnings from those with personal experience in developing countries, there are scientists and technologists in developed countries who believe the poor and undernourished will accept preselected and unmodified packages of scientific and technological information. A few books and a seminar or two are all that is thought necessary. This pattern of optimism was evident in 1963 at the UN Conference on Science and Technology for the Benefit of Less Developed Areas. However, the problem has proved more complex than anticipated then. What is the bottleneck - the substance of the science and technology, or the means by which it is transferred? The necessity of having to deal with problems within existing political, economic and social realities has become more evident. There is thus an obvious need to design new options and strategies to utilise science and technology to meet the indigenous social and economic objectives of people in developing countries. There are insufficient resources for everyone in these countries to live like their brothers in the affluent West, but development assistance can set the stage for their creativity to blossom within the context of their culture and resources.

Some developing countries have proposed policies of scientific isolation to protect traditional cultures from Western patterns of consumption and the omnipresence of technology. Perhaps the best known is the Chinese 'walking on two legs' policy adopted after the Russians withdrew in the 1950s. This policy has not been sustained. Singapore has been struggling to maintain a balance and President Lee Kuan Yew has spoken often about the difficulty of retaining cultural traditions while actively importing technology. The need for an appropriate balance is often overlooked, making this meeting of physical and social scientists so appropriate. The cultural barriers are such that there are many cases where people in developed countries have given up the struggles of transferring technology and adopted a 'survival of the fittest' philosophy, i.e. let the developing countries work out their own salvation. In some respects this is similar to the 'walking on two legs' policy. It has been called the 'lifeboat' theory, whereby those 'in' are safe while the others sink or swim. Personally, I do not believe it can succeed for the simple reason that those outside the boat will not remain content with their plight. At the same time, it must be recognised that the complexity of the problem has been grossly underestimated and if simple solutions were possible they would have been found long ago.

The objectives of S and T transfer are often confused. Generating self-reliance has been identified as the main objective and the subject matter offered should be a means towards that end and not an end in itself. A recent Pugwash[3] workshop of developing countries, held in India, stressed the need for developing countries to build up their own 'autonomous capability for problem solving, decision-making and implementation'. This includes the ability to generate, adapt, utilise and diffuse knowledge relevant to indigenous objectives. I suggest that therein lies the objective of development assistance and we should not be sidetracked.

President Carter recently announced the formation of a Foundation for International Technological Cooperation. Its basic purpose is to help developing countries 'find solutions to their scientific and technological problems and to help build institutions and train people in the less developed countries so they will be able to solve their own problems.'[4]

ORGANISATIONAL BLOCKAGES

It is common to hear that the barriers to acceptance and adoption of new technology lie solely in the recipient country. While I doubt if this is as true as often stated, the blockages are real. Some of the worst blockages are caused by the administrative structures of the government scientific agencies. Kazi[5] stated that 'the most stultifying element in government and semi-government research institutes (in Bangladesh) is the civil service system of command structure'. He called for a 'command structure suited to the genius of science'. I suspect the same can be said of many other countries. Many political leaders and administrators are not aware that scientific institutions need a different organisational structure from other public agencies. This situation has arisen partly because scientists from developed countries have over-emphasised the relevance of their particular aspect of science and have ignored the totality of needs in a country and the administrative disturbances overemphasis on one aspect can create. Others have oversold science to people not equipped to make balanced judgements. Dr Harada[6] of UNESCO has pointed out recently that there is a tendency for administrators to regard science and technology as being similar in quality and mutually interchangeable and competitive on the same terms. The Royal Society[7] examined this problem recently and concluded that developing countries would gain more from developing technological capabilities than from scientific expertise. This may be true, but it needs to be kept in perspective. Importing technology without building up an indigenous research capability perpetuates the inappropriateness of technological transfer.

The development of the applied sciences has added to the problem. Science is now often called on to justify itself in the same terms as technology; to create the impression that it can have an immediate, direct and finite impact on socio-economic problems. When expectations are not fulfilled immediately, all science tends to fall into disrepute and in some cases to be regarded as little more than an insignificant luxury, and so divorced from the real world that it does not warrant distinct organisational structures to make it relevant to developmental needs. Research is often regarded as being slow-yielding, low-yielding (or both) compared with other activities. This criticism is valid if research is not in tune with the requirements of the developing country. Harada advocates the fostering and establishment of a viable and self-critical corps of scientific societies to explain the relevance of research to development. In this way scientists could participate in the formation of appropriate science policies with a suitable balance between the resources used for science and technology.

Within some developing countries technological transfer is often equated with the needs of the wealthy who live a predominantly western lifestyle in what amounts to a sociological island. Western technological ideas can thus be imported, and applied with little modification, to meet most of the housing, transport and entertainment needs of this small, politically powerful proportion of the population. This can result in the importation of massive reserves of technology which are mistakenly thought to be required by all. In many respects the rich and the poor live in different cultures with little technological commonality. When I lived in South East Asia my role, superficially at least, was to undertake a research program. However, my real aim was to demonstrate that well-conducted research could be pertinent to the welfare of the mass of people. It was necessary to demonstrate that this requires well-trained and innovative scientists who could develop their careers with dignity. Furthermore, it required suitably equipped and maintained laboratories.

Success depends on convincing politicians and senior administrators that an investment in indigenous research can show a worthwhile return in human welfare. The fact that the work may be related to a particular scientific discipline is really of secondary importance.

Achieving the objectives of development assistance requires a sensitive understanding of administrative and cultural constraints. Some of the greatest problems are created by expatriates who, with singleness of mind, ignore local social mores or refuse to accept that their efforts might have drastic effects on local customs. The mistake of a visitor does not remain his. He goes home and the mistake is left to be solved by local people, if at all, and he often joins the critics who blame the local people for not applying his technology. It often takes very little to create a social imbalance in a poor and fragile society. Tjokoda[8] pointed out recently that the introduction of such basic items as bathrooms and toilets to Balinese houses had led to a breakdown in social contact and communication between villagers, who formerly met at the local stream each morning and evening. Even the gift of a vehicle can cause a ripple of resentment. Advising a particular person and unwittingly bypassing the locally accepted authority can spell doom to S & T transfer and even lead to sabotage.

Ironically, the application of scientific and technological innovation itself has created many of the current problems. As living conditions have improved where technology is generated and applied, the gap between the rich and the poor has been widened. Furthermore, the resources required to sustain the technological advances have tended to create technological colonialism, which perpetuates the differences. For example, tea, oil palm, and copra are produced on land which could be used for food production. In many cases these industries depend on continued low labour costs. It is true that developing countries need export incomes and that they often have little to sell. However, the promoters of the new economic order point to the growing imbalance between prices received for goods and prices paid for goods from the developed countries.

Paradoxically, science and technology are now being called on to solve the problems they have in part created.

COOPERATION BETWEEN NATURAL AND SOCIAL SCIENTISTS

Assistance to recipient countries from natural and social scientists and technologists should be integrated rather than delivered in separate packages. While such integration is all too rare in developed countries, I suggest that the situation is even worse in developing countries. Leaders rarely appreciate that science can, and must, be involved with cultural and social affairs. Sumitro,[9] the former Indonesian Minister for Research, speaks of the 'social function' of science. He points out that once the relevance of science and technology to societal needs is recognised as a desideratum, and even a necessity in view of limited resources, there is essentially no dichotomy between development and applied research and technology. Kabir,[10] on the other hand, differentiates between research and science and points to the way much of the research in India has been artificially sustained simply because it has been fashionable. Whereas the industrial countries have a long history of scientific and technological exposure and have, since the Middle Ages, built up an instinctive community 'spirit of science', the developing countries unfortunately often attempt an instant technological revolution isolated from cultural influences. To pursue a course of research and technology, and hope a 'spirit of science' will follow, puts the cart before the horse.

I have, perhaps, over-emphasised this situation to illustrate the point that the export of science and technology has to be viewed as being appropriate by the recipient. The 'spirit of science' takes time to grow and too rapid an injection of science and technology and at an inappropriate level of sophistication can be of negative value. The expatriate scientist often has to accept something less than he thinks professionally desirable in order to work at the appropriate level. He has to be prepared to let his indigenous counterparts learn by their mistakes and let his ideas be influenced by the recipient country, and even within it, because the technology appropriate to one sector of the community may be quite inappropriate to another. Often the affluent are well motivated to import technology while the poorer and less educated have less well-defined objectives. This situation can create significant pressures being placed on the expatriate. He must recognise that the cultural character of a recipient country will influence the priorities it gives to research. His 'spirit of science' will be reflected in his research approach whereas his counterpart's may differ markedly. Schumacker[11] compares the western approach with that of a Buddhist. The former measures standards of living by the annual consumption of resources - the more consumed the higher the standard. The Buddhist considers this approach irrational and aims at the maximum well-being with a minimum of consumption. These two approaches can lead to very different research priorities and scientific and technological policies. The expatriate also should be aware that what he sees as the 'real' needs of the country may not agree with those of the country's leaders. He will often have to make unpleasant choices as to the levels of society he should assist and be satisfied with a compromise.

Care needs to be exercised in assessing the relative importance of science and technology transfered to developing countries. Over-emphasising its value is not only misleading but can have disappointing consequences. A good example can be taken from the area of public health. Studies[12],[13] in the United Kingdom and the United States suggest that the decrease in the morbidity and mortality caused by communicable diseases was due more to socio-economic reasons and improved industrial conditions than to drugs, vaccines and other more apparent measures. Newell[14] points out that, while such conclusions are unlikely ever to be 'proved', there are examples in the developing world where health standards have improved following the correction of social and economic abuse, with the addition of very few other measures. It should not be concluded, however, that science and technology could not have been effective if applied correctly. Nevertheless, it is at least an open question, and it can be dangerous to put too much emphasis on scientific excellence and specific technological transfers. Newell points to the advice of donor countries leading to massive amounts of money being spent on sophisticated hospitals in developing countries which serve only a fraction of the population. It may be more effective to try to integrate health considerations in regional development projects.

Similarly, many reasons have been put forward to explain the causes of hunger in developing countries. Perhaps population increase has been given more importance than it should. While it is certainly important, other more general factors, such as distribution of food within a country and unemployment are equally important. Some of these factors are brought out in a report by the Indian Association for the Application of Science to Human Affairs.[15] The report emphasises that the basic problem is not lack of food but the lack of the means to acquire it due to lack of skills, work, and employment.

TRAINING

Since World War II, over 17 000 overseas students have been trained in Australia under the Colombo Plan; if private students and other aid schemes are included, this total rises to over 60 000. Universities obviously have been, and are, heavily committed to the training effort, although in recent years the number of students has declined. Nevertheless, trained minds rank highly as a mechanism in the transport of science and technology.

The training received by students from developing countries is often criticised as being unsuitable. While some imperfection is inevitable in such a large program, many young leaders in South East Asia speak freely of the benefit of their training in Australia.

I suggest that Australia can capitalise on what has been achieved by its training programs by:

. providing more opportunities for those scientists and technologists with overseas training (not necessarily Australian) and 5-10 years experience in their home countries to work in Australian universities, scientific laboratories, and technological organisations (public and private) for significant periods;

. offering fellowships for potential leaders in science and technology to spend 12 months working in Australian companies and scientific institutions to learn management techniques, goal setting, business organisation, etc. - something akin to the Harkness Fellowship;

. giving more emphasis to technical training at colleges and incorporating practical experience in selected engineering workshops and analytical and biological laboratories.

Overseas students face many difficulties in adjusting to Australian universities and cultural differences, especially during the first year. The change from authoritarian dependence to individuality, combined with linguistic problems and loneliness, can be traumatic. However, the return of the student to his home country can be equally distressing. Adjustment problems can be exacerbated by resentment from peers who have not been overseas, frustrations at having to 'scale down' his work due to lack of equipment and finance, and a lack of skilled support staff. Often, a sudden increase in responsibilities well beyond the scientist's previous experience prior to, or during, his overseas training creates additional adjustment problems. The returnee and his peers have to adjust to each other and their respective situations, a process which can often take a considerable time. Without doubt, some of the training received in Australia leads to inappropriate technological transfer. However, it is unrealistic to expect Australian university faculties to make major changes in formal courses or even for one university to specialise in training for overseas needs, as Wageningen did for the Dutch colonies. It may be possible, though, for Australian universities to develop closer ties with overseas educational and research institutions. A possibility is to build on the program conducted by the Australian Asian Universities Scheme (AAUCS), where students undertake research projects in their own countries, by facilitating a much closer relationship between the student and his Australian supervisor. CSIRO and the Australian Development Assistance Bureau (ADAB) have a current arrangement in Indonesia with the Institut Pertanian Bogor (an agricultural university) whereby students receive fellowships from ADAB, register for MSc and PhD courses at IPB, and do research projects at the Centre for Animal Research and Development under CSIRO guidance. In this way students work on research projects relevant to local needs and the university builds up its postgraduate training expertise.

CONCLUSIONS

This paper has probably done little more than point out the complexity of the development assistance problem. There is no obvious, simple, or speedy panacea to the problems associated with exporting and importing science and technology which is appropriate to development. The scientific community needs better mechanisms for combining the contributions of natural and social scientists. In addition, a bridge is needed to link these scientists and technologists to the political and bureaucratic community. I suggest:

- Academics and learned societies, representing both natural and social sciences, in developed countries foster closer collaboration with their sister organisations in developing countries. While numerous conferences have been held by both natural and social scientific groups on this topic, they have usually been isolated meetings within disciplines rather than cooperative meetings between disciplines. This meeting is an all too rare example of the latter. More practical moves are required. Focusing on and assessing the scope of needs in a geographical area, or alternatively, a subject that can be related to a wider area are examples. It is essential, however, that natural and social scientists from both developed and developing countries jointly contribute to the discussion and selection. This suggestion naturally requires finance, but it could well be relevant to bilateral funding organisations.

- A better understanding and closer cooperation within Australia between scientific and technological bodies and national organisations such as ADAB and the Department of Science. Some moves to build bridges of this nature have been initiated. For example, ADAB has formed a Consultative Committee on Research for Development (CCRD) and CSIRO has formed the Centre for International Research Cooperation (CIRC), with the support of the Department of Foreign Affairs. While these moves should be encouraged, much more needs to be done. Too often assistance projects suffer from over-emphasis on political influences and insufficient emphasis on scientific and sociological considerations. At the same time, scientific circles often misunderstand the magnitude of political pressures, both within

Australia and overseas. Effective scientific and technological transfer is sufficiently complex to require our most experienced administrators and scientists.

Efforts need to be made to select a few activities requiring inputs from natural and social scientists and development assistance agencies and to use concrete examples to pinpoint administrative and scientific management problems.

It is obvious that these simple suggestions will not solve a problem of such complexity. They may illustrate, however, the need for scientists and administrators, in developed and developing countries, to take a more comprehensive and coordinated approach, while taking care to ensure that their efforts are focused on practical problems of importance to recipient countries.

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THE TRANSFER OF SCIENCE AND TECHNOLOGY: AGRICULTURAL AND BIOLOGICAL SCIENCES IN AID TO DEVELOPING COUNTRIES

BY

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INTRODUCTION

Science and technology tend to grow exponentially. This property, responsible for the pace of change in our lives, tends also to widen the gap between the more developed and the less developed countries of the world. Every effort must therefore be made to increase the scientific and technological capacity of developing countries as rapidly as possible. The most effective ways of achieving this on a continuing basis need to be found, as the processes of innovation will continue. This is presumably the central goal of the United Nations Conference on Science and Technology for Development (UNCSTD), as many developing countries perceive their lesser scientific and technological expertise to be a major cause of their slower development. They also recognise, however, that technological progress should not be an end in itself, but subordinate to the paths of economic and social development which they choose to follow.

SCIENTIFIC AND TECHNOLOGICAL AID

Occupying as it does a position between the extremes of the development spectrum, Australia is well aware of the very different problems of, and attitudes to, the transfer of technical expertise to more and less developed countries. Upstream movement to more developed countries is easy provided the channels of communication are adequate, as they usually are. In fact, in the area of high technology it is all too easy for the more developed countries to adopt and gain greater advantage from a technological innovation than can the country of its origin. A relevant example from Australia is atomic absorption spectroscopy; the Interscan guidance landing system may provide another. In these cases the key concepts originated in Australia, but our industry was not able to undertake their full technological development, whereas in the case of Self-Twist spinning it could do so. These examples illustrate the need for a balance between scientific and technological capacities within each nation. They also indicate that Australia is no stranger to the frustrations of seeing other countries take technological advantage of local scientific advances, as Nigeria has recently experienced in the processing of cassava flour. Such occurrences are an inevitable consequence of technological progress, and should not be made an excuse for not attempting indigenous technological development.

Downstream transfers of expertise to less developed countries are less inherent in the processes of technological communication than are transfers to more developed countries, hence the need for aid. Moreover, transfers downstream encounter rather different problems in the case of science from those for technology. Scientific knowledge is, or should be, public knowledge, open and available to all through the journals of science. It is also universal in its application, since race, religion and nationality have no bearing on the findings of science. In theory, therefore, there should be no barrier to the transfer of scientific understanding between countries. In practice, however, it depends on the availability of trained and able scientists who have adequate access to, and the motivation to keep abreast of, an increasingly expensive and multilingual scientific literature and have opportunities to discuss new concepts with colleagues, both at home and overseas. Many developing countries are constrained in these respects. We should note, in this context, that the nine Australian journals of science published jointly by CSIRO and the Academy of Science must have contributed a great deal to the diffusion of science to developing countries through the large number of copies sent regularly to their research institutions, either gratis or in exchange for local journals.

Unlike the transfer of science, that of technology is not entirely free and open, often being limited by patents and industrial secrecy. Nor is it universally applicable, being in many cases highly environment-specific because of differences in sites, conditions, economies and cultures. Technology must often be adapted to local conditions, a process requiring managerial skills and experience as well as resources, in industry as well as in agriculture and medicine. In essence, the successful transfer of technology requires parochialisation as much as the transfer of science requires generalisation. The transfer of technology may therefore appear more attractive, as well as more urgent, to developing countries than building up their scientific capacity. For the same reason, it is clearly a more difficult and hazardous task for the developed donor countries to undertake. Their scientific status is not at risk when they undertake the transfer of science, but their standing in the eyes of the Third World may be all too easily jeopardised by the difficulties of local adaptation of technology. This is a central dilemma which UNCSTD must address.

While the developing countries give priority to technology transfer, there are many reasons why developed countries tend to emphasise the transfer of science. Science is more universal, freer from commercial restrictions, more readily communicated, and has greater support from public funds. Its practitioners can therefore be called on more readily to participate in aid projects. A reputation for scientific excellence enhances a country's status in the eyes of the Third World, and developed countries tend to appreciate more fully the crucial role of enhanced scientific capacity in technological development. Also, scientific contact is one of the most acceptable and unobtrusive ways in which Governments can establish communication, and it has often served as a substitute for more substantive but otherwise unachievable political contacts.[1]

AGRICULTURE AS A COMPONENT OF TECHNICAL AID

The improvement of agricultural productivity is given high priority by the Governments of most developing countries. Increase in local food production barely keeps pace with the increase in population, and has even failed to do so in several African countries. Whereas the increases in agricultural production in developed countries have come mainly from increases in yield per hectare due to the use of improved technology, those in developing countries have come largely from increases in the area of land cultivated. The scope for further increases in arable area is limited, particularly in Asia. Consequently, if the developing countries are to avoid dependence on imported food or on the use of marginal land for agriculture, both of which can be expensive as well as politically undesirable, they must give high priority to the improvement of their agricultural technology. Earlier five-year plans often put particular emphasis on the development of manufacturing industry and infrastructure as their primary objectives. In more recent plans the intensification of agriculture has received higher priority, as in India.

Three further reasons for concentrating this discussion on agriculture may be noted. The first is that most agricultural research is supported by public funding, whereas much industrial technology is developed in the private sector. Consequently agricultural innovations are more openly available for transfer to developing countries, as also are the expert advisory staff concerned with them.

Secondly, agricultural innovations are at the extreme end of the technological spectrum in their requirement for local adaptation. Some industrial innovations require only slight modification for successful transfer to developing countries. On the other hand, virtually all agricultural technology requires adaptation to local environmental and socio-economic conditions before it can be used successfully. Agricultural aid therefore exposes more clearly the relations between technology and its supporting sciences in the transfer process.

Thirdly, agriculture is the sector in which large-scale, cooperative multilateral research specifically focussed on the problems of the developing countries, and located in them, has been most effectively organised. The nine international agricultural research centres (IARCs) funded by the Consultative Group on International Agricultural Research (CGIAR), for a total expenditure of $85 million in 1978 and probably $105 million in 1979, have already contributed a great deal to the transfer of science and technology to developing countries. We are therefore in a better position to compare the effectiveness of various organisational frameworks for technology transfer in the agricultural sector.

Given all these considerations, it is not surprising that agriculture is a prominent component of the technical aid provided by many developed countries, such as France, Sweden and the United Kingdom, as well as by the World Bank.

AUSTRALIAN TECHNICAL AID

In view of the great strength of Australia in agricultural research, partly due to the concentration of resources in this area by CSIRO in its earlier years, technical assistance in agriculture should also be prominent in our aid profile. In addition, Australia is one of the very few developed countries with some tropical agriculture and therefore has some major problems of agriculture in common with developing countries in the tropics. Similarly, we also have large areas of agriculture under semi-arid conditions which are closely comparable with those in many developing countries in North Africa and the Middle East.

Several countries in these latter regions are receiving strong technical assistance in development from staff of some of the State Departments of Agriculture, particularly of Western Australia and South Australia. However, the potential demand for such help exceeds the capacity of the States to provide it without detriment to local needs. CSIRO, many Australian universities, and commercial consulting firms also provide substantial technical assistance to developing countries in the area of agriculture. A compilation of all these sources of agricultural advice would be useful, as a complement to that provided by the Australian Development Assistance Bureau (ADAB).

The aid profile of ADAB and its predecessors has changed substantially in recent years. Conclusions based on individual reports cannot be generalised, but the following perspective emerges from the 1978/79 Budget paper.[2] Most Australian aid is bilateral, the contributions to multilateral agencies comprising only about 15% of the total. To a degree this is due to the high proportion of aid going to Papua New Guinea (51% of the total). Of the multilateral aid, only about 4% goes to scientific and technical agencies other than those of the United Nations. Of the bilateral aid in the 1975/6 Report of ADAA,[3] only 16 or 22% (depending on whether Papua New Guinea was included or excluded) was assigned to agriculture. The more important sectors were the development of public utilities and education. Thus, even if Papua New Guinea is excluded as a special case, the science and technology component of Australian government aid has been a relatively small one in terms of total expenditure.

A high proportion of Australian aid funds (apart from those for administrative support in Papua New Guinea) goes towards education (especially via the Colombo Plan in the past) and to infrastructural development such as railways, roads, bridges, dams and hydroelectric projects, telecommunications and other public utilities given high priority by our neighbours in South East Asia and the Pacific. This is partly because they are seen as major constraints on their agricultural development. Australian technical expertise is used in many of these projects. For example, the Snowy Mountains Engineering Corporation is helping to design water control and hydroelectricity projects in the Pah'ang and Trengganu River Basin projects in Malaysia and in the Bui Hydroelectric project in Ghana. Although agricultural projects are not a dominant component in terms of total aid expenditure, they are an important part of Australian technical aid in terms of their total number, the number of developing countries receiving them, and the number of experts engaged. Indeed, according to the recent CARIS survey, only the USA, France and the United Kingdom have posted more agricultural experts in developing countries. Agricultural aid also comprises a central component in a number of integrated regional development projects, such as that at Zamboanga del Sur in the Philippines. The Australian National Paper for UNCSTD states that almost 90% of expenditure on the research components of bilateral projects is in the field of agriculture.[4]

REQUIREMENTS FOR EFFECTIVE TECHNOLOGY TRANSFER

(1) Adaption, not Adoption

There are some elements of industrial technology which can be transplanted to developing countries with little modification. However, most medical and all agricultural techniques and equipment depend on environmetal and socio-economic conditions, and are likely to require local adaptation if they are to be successfully transferred. Agriculture is at the extreme in this respect, since local adaptation is required not merely at country level but even to village, farm or field level. As this is clearly beyond even the most ambitious aid program, effective technology transfer depends on understanding and amplification through the recipient national programs and systems. Without this, the impact is likely to be only local and temporary. Wherever possible, therefore, the aim should be to strengthen and complement national programs and to help build up indigenous capacity for on-going development.

(2) Science and/or Technology?

It is rather ironical that agriculture, the sector in which technical aid is most often requested and given, is, by virtue of its strong interactions with environment, the area in which it can be least directly transferred. But this has the advantage of reminding us of the need to maintain a balance between science and technology, since successful local adaptation requires a clear understanding of the scientific background of the problems. For example, the improvement of pasture production and soil fertility in Australia through nitrogen fixation by legumes has profited in many ways from the strength of Australian research into all aspects of the fixation process. Examples include the recognition of the key role of molybdenum; the development of more effective methods for applying the symbiotic Rhizobia to seeds; the identification and selection of the most suitable strains of Rhizobium for various species and conditions; and the establishment of the Australian Inoculant Research and Control Service to set standards and monitor the effectiveness of rhizobial inoculants. As a result, many developing countries have sought and received technical help from Australia in connection with their use of rhizobial inoculants.

Given the urgency of solving a wide range of technological problems in developing countries, it is understandable that Governments are tempted to concentrate on technology transfer and capacity, leaving science to look after itself. They may be encouraged in this direction by the Royal Society paper for the UNCSTD Conference,[5] in which it is stated 'it is neither necessary nor profitable for developing countries to support a large amount of fundamental research unless it provides a strategic base for applied research relating to their own development.' For industrial technology this may well be so, but in areas such as agriculture, natural resources and medicine there is a need to maintain a balance between science and technology if the long-term capacity for technological change is to be fostered.

(3) Appropriate Technology

It has been fashionable in recent years to carp at the transfer of 'high' technology in all sectors, and to demand more 'appropriate' technology to meet the problems and conditions in developing countries. The level of technological sophistication current in developed countries may require inputs, skills and services which are unavailable or burdensome to developing countries. On the other hand, simpler technologies may yield products or effects on the environment of lower quality than are currently acceptable in developed countries, thereby leading to complaint by developing countries that they are being exploited or offered second-rate technologies which perpetuate their underdevelopment. In some cases, such as grain storage, the appropriate technology may be simple; in others, such as the utilisation of solar energy, it may be advanced.

In this situation, developed countries with technologies that are not the most advanced in the world, as is often the case in Australia, have certain advantages in the transfer process because their level of expertise is closer to that in the recipient countries. It is one of the weaknesses of the present international system that aid flows most strongly and directly from countries with the highest technology to those with the least. A catenary system in which each country helped those a few steps down the development ladder would be more effective. An interesting experiment with this concept has been initiated by Sweden. The Swedish Agency for Research Cooperation with Developing Countries (SAREC) is financing scientific assistance from Senegal to Guinea-Bissau in the field of agricultural research.[6]

In the area of agriculture, Australia has developed an effective, relatively low-input system of cereal production based on the use of superphosphate and legume-based ley pastures composed of species originally introduced from Mediterranean countries. Now the improved strains of these plants, and the management systems for them, are being reintroduced to their countries of origin, particularly in North Africa and the Middle East. They constitute one of the most valuable components of Australia's aid to these countries precisely because of the environmental similarities which made these plants useful to Australia in the first place.

The question of appropriate technology has been bedevilled by a lot of wishful thinking which has led to much unfair criticism of aid projects. Nevertheless, it offers developed countries like Australia a special opportunity in the process of technology transfer.

(4) Integrated Aid

One possible reason for the lack of appreciation of many of Australia's valuable pasture plants in their countries of origin was that each on its own, without interaction, without improved nutrition and without effective management, was not particularly impressive. As so often in agriculture, it was the combination and interaction of several components that was important. The performance of the grasses was greatly improved by the presence of legumes, with their ability to fix nitrogen symbiotically. That crucial ability depended in turn on the provision of phosphatic fertilizers and, in some soils, of other nutrients, such as molybdenum. Grazing management to maintain an effective balance between grass and clover and to provide forage throughout the year was also essential.

Clearly, therefore, assistance programs must deal with combinations of technical inputs rather than single factors, and provide complementary aid of other kinds. But how widely must the aid net be cast? High input cropping requires access to fertilizers and pesticides. How are supplies of these to be provided? Are the road and transport systems adequate for their prompt delivery to every farm? The new dam serves a well-planned system of large irrigation canals, but how efficiently and equitably is the water delivered from these to the individual fields? Is credit available for the inputs? And when the unusually large crop is harvested, are there adequate storage and transport and milling capacities? Even if there are, is there adequate financial management to prevent a disastrous fall in prices, and the political will to see development through? If not, only a sour taste may be left in the mouth of those so aided, and their willingness to try new ways may be blunted. These are the reasons why such a high proportion of the aid requested by developing countries and funded by Australia is for infrastructure, and for the emphasis on integrated development projects.

It was common in the 1960s to say that the export of new technologies to developing countries was much less difficult than the export of the attitudes required to put them to good effect. Perhaps one of the most important lessons we in the developed countries have learned since then, at least in the agricultural sector, is that even the poorest farmers in the developing countries are quick to use new technology when it is possible and profitable for them to do so. For example, the adoption of high-yielding varieties of wheat in the Punjab was quite as rapid as the earlier adoption of hybrid maize in the USA. But adoption has often been prevented by inadequate infrastructure or credit facilities, or the technologies have been only marginally profitable, and risky as well under the farmer's conditions.

(5) Consequences of the New Technology

The traditional life styles of developing countries are often finely tuned to local conditions, and have evolved into equilibrium with them. In developed countries, on the other hand, such is the pace of change that we live in a state of disequilibrium.[7] New technology usually brings both advantages and disadvantages. Agencies concerned with technology transfer must expect so-called second generation problems to emerge in aid projects however much experience and forethought are brought to bear on them in the planning stage. Nevertheless, every effort must be made to foresee the consequences, as in the Thai-Australian Chao-Phya research project at Chainat, which carefully examined the long-term effects of double cropping on the trends in salinity and soil fertility.[8]

Even more difficult to predict than the physical and biological consequences are the socio-economic ones. Because of what has been called 'the fuedalism of technology', existing social discrepancies may be amplified. Small scale farmers, for example, may gain less advantage from new agricultural technology than do large scale ones. Usually this is not because there is any technical advantage to the larger farmer, but because he has readier access to credit, inputs and markets. Thus, even when successful in raising local production, technical aid may stimulate unrest as a result of greater social inequalities.

One possible solution to this dilemma is to concentrate on what have been called scale-negative technologies, that is those conferring relative advantage on the smaller-scale operators. But although considerable thought has been given to identifying them in the agricultural sector, no sure examples have yet been found. Farm surveys in India have shown that intercropping is practised to a greater extent by small farmers, but advances in the techniques of intercropping would hardly be scale-negative in that they could just as readily be used by large as by small farmers. Moreover, concentration on the problems of the poorest sector can lead to relatively low-yielding research. Science should not be expected to stand proxy for social reform.

(6) Geographic Aspects of Technology Transfer

Although much technical aid is truly international, there is nevertheless a strong 'longitudinal effect' evident in relations between donors and recipients, and implicit in the current 'north-south' terminology. For Australia this implies concentration of our effort in South East Asia and the Pacific.

This area of interest poses no problems for some kinds of technological aid, such as the help given by the CSIRO Divisions of Building Research and Chemical Technology to Malaysia, Papua New Guinea and the Solomons on the properties and potential uses of their timbers. In agriculture, on the other hand, much of our experience is more relevant to homologous climatic zones in North Africa and the Middle East for our temperate pastures, and in South America for our tropical pastures. For our nearest neighbours, therefore, Australian agricultural expertise is often not particularly relevant.

One format for dealing with this problem is exemplified by the ADAB-funded project for pasture improvement in Malaysia managed jointly by the CSIRO Division of Tropical Crops and Pastures and the Malaysian Agricultural Research and Development Institute (MARDI). Here the out-posted Australian research workers are directly investigating Malaysian problems in the light of their previous Australian experience and with strong back-up support from their colleagues in Queensland. Given the different agricultural conditions throughout South East Asia compared with those in Australia, the provision of aid with strong home-base support for outposted staff will be crucial to the effectiveness of Australian agricultural aid in the region. Both the United Kingdom and France have developed this principle effectively. In fact both have large research organisations wholly devoted to the agricultural problems of developing countries, such as the Centre for Overseas Pest Research and the Tropical Products Institute in England and ORSTOM and GERDAT in France.

The developing countries of the Pacific region are in particular need of help of this kind. Being many, small and diverse, they tend to be neglected by even the most conscientious donor countries, as evident in the Swedish UNCSTD Report.[6] The Australian and New Zealand aid programs both provide a variety of infrastructural and technical aid, but we often lack agricultural experience relevant to their conditions. Nor is it easy to strengthen their national research systems as their small size often means that only one specialist in each area is needed. Continuity of training and expertise is therefore difficult to achieve. There is a special need for aid throughout the region on Pacific-specific problems which can be effectively tackled by an Australian research group with a specific mandate for the task. The Australian national paper for UNCSTD[4] indicates (p. 85) that a take-off point has been reached in directing our research resources towards the solution of Third World problems. Our Pacific neighbours have a strong case for such help.

EPILOGUE

Thirty years have passed since President Truman enunciated Point Four of his 1949 message to Congress, with its call for the transfer of aid for self-sustaining economic development. The forms and motivations of aid have changed greatly in that time, and there has been increasing recognition of the need for more effective transfer of science and technology. In the last 10 years, since Lester Pearson's 1969 report to the World Bank, there has also been increasing recognition that economic development should be undertaken on the basis of partnership between the rich and the poor nations of the world.

In the area of agriculture it is clear that we all stand to gain from such cooperative enterprise. For example, the new varieties of wheat and rice bred by the international agricultural research centres have proved valuable as parents in the plant breeding programs of

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developed countries, including Australia, as well as in those of the developing countries. Likewise, their comprehensive collections of germplasm resources of the major crops will benefit all nations in the future. The development of tropical agriculture in northern Australia is bound to profit from improved understanding of the related problems of developing countries. Aid programs for the survey and control of diseases in adjacent countries, such as of foot-and-mouth disease in Indonesia or of the screw worm in Papua New Guinea, are bilaterally useful, just as multilateral cooperation in locust control is of benefit to all endangered nations.

The effective transfer of science and technology to developing countries is a complex task, highly dependent on gifted and dedicated individuals. In the long term it succeeds only to the extent that it strengthens the indigenous scientific and technological capacity of the recipient nations, and to the extent that it is integrated with the many other aspects of national development.

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WORKSHOP DISCUSSION

TRANSFER OF SCIENCE AND TECHNOLOGY TO DEVELOPING COUNTRIES

REPORTER

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1. AUSTRALIAN DELEGATION TO UNCSTD

Recommendation:

That the Workshop adopt a resolution calling on the Australian Government to:

(a) name the Australian delegation as soon as possible, and

(b) appoint a technical advisory committee to assist in the preparation of the delegation's brief. The proposed technical advisory committee should include scientists, social scientists and technologists with knowledge and first-hand experience of the transfer of science and technology to Third World countries.

In view of the fact that other countries will be represented by or advised by scientists and technologists at UNCSTD, this Workshop should recommend that some members at least of the technical advisory committee should accompany the Australian delegation to Vienna.

Recommendation:

That the three Academies which organised this Workshop indicate their willingness to nominate members for the proposed technical advisory committee.

In making these recommendations, the members of the syndicate were concerned to ensure that, in deciding on the position that Australia will take at UNCSTD, proper account be taken of the experience of Australian scientists, social scientists and technologists in the problems of transferring science and technology to Third World countries. The extent of this experience has been revealed at the series of seminars and workshops conducted in Australia to prepare for the UN Conference.

2. AVENUES FOR THE TRANSFER OF SCIENCE AND TECHNOLOGY TO DEVELOPING COUNTRIES

The work of the multi-national agencies, Government to Government and institute to institute contacts, overseas investments by manufacturing and mining industries, the work of commercial consultants and of voluntary non-government organisations were all seen as valuable avenues for the transfer of science and technology.

The members of this syndicate agreed that, whether the transfer of science and technology took place on commercial or concessional terms, it was important to do two things. Firstly, to establish mechanisms for the documentation and dissemination of experience gained by Australians who have worked on technical projects in developing countries. Secondly, to establish effective procedures that would avoid, as far as possible, the undesirable social, economic and cultural consequences that have often occured in the past when science and technology have been transferred to Third World countries.

3. COMMUNICATION OF EXPERIENCE

One of the perhaps unexpected side-effects of the seminars and workshops conducted in preparation for UNCSTD has been the realisation that Australian scientists, social scientists and technologists have had practical experience of working in almost all overseas countries on a great diversity of projects. The problem is to know how to identify and benefit from this expertise. The old-boy and old-girl network is clearly inadequate.

Recommendation:

That the three Academies organise further discussions of the subject of technology transfer to developing countries.

The members of the syndicate felt such discussions should involve representatives from both government and non-government agencies with relevant overseas experience.

Recommendation:

That the three Academies appoint a working party charged with the task of recording Australian experience in development in Third World countries.

4. AVOIDING UNDESIRABLE CONSEQUENCES OF TECHNOLOGY TRANSFER

The members of the syndicate attached great importance to the search for new procedures that would reduce in future the possibility of undesirable social, economic and cultural changes occurring as a result of technological innovation in developing countries (cf the papers by Jarrett, Gurnett-Smith and Evans).

The syndicate strongly endorsed Evans' call for an integrated approach to development. Both agricultural and industrial development depend for their success on the existence of, or the provision of, an adequate infrastructure. Van Vugt refers to the importance of efficient transport and communication and reliability of power and water supply. National political and administrative capabilities will play a vital role in helping to avoid disruption from technology transfer.

Other suggestions for improvement of the process of technology transfer included:

- the need for more careful planning and monitoring of projects and programs. This should be done by multi-disciplinary teams that must include social scientists;

- the need to develop a smaller number of more comprehensive programs; and
- the need to start small, to hasten slowly, and to retain the flexibility to make necessary changes in the light of experience.

The syndicate agreed that disruption to social patterns was inevitable, but that it should be kept within tolerable limits. Wherever possible, the people whose lives would be changed by proposed innovations should be consulted and their wishes should be respected.

5. RESEARCH IN AUSTRALIA

Attention was drawn to the fact that not more than 2% of the world's resources in science and technology are devoted to studying the problems of developing countries. Attention was also drawn to the need for more research on development and to the need to interest more Australian scientists, social scientists and technologists in the problems of the Third World.

Recommendation:

That this Workshop adopt a resolution requesting the Australian Government to provide separate funds for grants in aid of research in Australia relevant to the problems of science and technology in developing countries.

The syndicate recommends that these funds be administered by ADAB with the advice of its CCRD. It also recommends that consideration be given in the near future to setting up a separate institute (possibly by expansion of an existing group) for the study of science and technology for development.

The recommendation should be brought to the attention of ASTEC and relevant Ministers.

6. TRAINING IN AUSTRALIA

The members of the syndicate saw a need for a better briefing of Australian scientists and technologists on the political, geographical, economic, religious and social conditions of the developing countries in which they were to work. Emphasis should be placed on the need for a sensitive and sympathetic approach to the people of those countries.

It was proposed that the three Academies might assist in the better briefing of Australians preparing for work in Third World countries. In some cases such briefing would need to include short technical courses. Early visits to other Australian projects in the overseas country concerned have been found helpful and there are advantages in providing language training overseas, within its cultural context.

The relevance of some of the training given in Australia to students from Third World countries was questioned. The aim must be to evolve towards self-reliance in technical and university education, and in research, extension, and development, within the recipient country. Therefore, there would be an increasing need for Australian scientists, social scientists and technologists to visit the developing countries to give advice in these areas and for cooperative studies.

The importance was stressed of giving training to students from the developing countries at all relevant levels. Three appropriate levels were defined: for survival, for raising living standards, and for high technology. The question is, are we capable of providing training in Australia at all three of these levels? How often do we choose the appropriate level for students from the developing countries?

7. TRAINING OF COUNTERPARTS IN THE DEVELOPING COUNTRIES

The syndicate considered that many fields of training could be conducted more effectively in the developing countries. Training of counterparts is an essential part of the process of creating self-reliance in the recipient countries. Such training should not be too narrow. It's not enough just to learn the job in hand. Counterpart staff need to gain sufficient depth of understanding to cope with new situations. In addition, the availability of indigenous counterpart organisations and staff is an important consideration in assessing the feasibility of new projects and programs.

SCIENCE AND TECHNOLOGY ON TRIAL

PANEL - JUDITH WRIGHT
ANN FORWARD
SUSAN RYAN
BRIAN NOAKES
JOHN BIRCH

CHAIRMAN - ARTHUR BIRCH

INTRODUCTION

As part of the Workshop, a panel of five non-scientists, non-technologists questioned the participants from a lay point of view on the application of science and technology for development. The reason for organising this session was twofold: to assist in promoting public debate, and to inject into the middle of syndicate discussions some community views from the consumers of research and technology. It was not accidental that three of the invited panel were women. Many scientists and technologists do not realise the vehement and deeply felt criticisms which are levelled at their activities, some of which were made manifest by the panel. Not all of the panel's comments were criticisms, and it was clear that the panel itself, like the community, was divided. The scientists reacted to some criticisms with shock and dismay, with counter statements which amounted to accusations of ingratitude and misunderstanding. Perhaps the format of the session was not appropriate for the desired exchange of views. It was made clear that a mutual education exercise is required, and that scientists and technologists should accept that their case is at least not self-evident. The community, on the other hand, should be at least as aware of the benefits as of the problems.

In the debate which followed the presentation of the views of the panel, the accountability of the scientific community was raised. The point was made that virtually all scientific research in Australia was financially accountable. It was noted, however, that, by and large, research into social sciences was not accountable.

Perhaps it would be fair to suggest that the forum accepted that researchers, both in natural science and social science, could not give of their best in an atmosphere of close public supervision. However, the key point seemed to be that the community wants to communicate its desires and fears more effectively to the people whose work, whether it is specifically socio-economically directed or concerned with the advancement of fundamental knowledge, will change the course of the community's development. It also wants to know just what scientists and technologists are doing.

Despite political mechanisms, there is a feeling that scientists and technologists are intent on change, whether of understanding or technological capabilities, with little sympathy for people whose lives are changed as a consequence without their consent. The social scientists, as intermediaries, might intervene beneficially in predicting and controlling change. In the Harrisburg aftermath, hard questions are being asked of scientists, some of which might more appropriately be directed to the politicians and economists.

The proceedings really only scratched the surface of the area of public involvement in scientific decision-making. Members of the public gallery wanted to explore this question but were prevented by lack of time.

The papers presented by the five members of the panel follow. As noted, there was not a very effective exchange of views with the scientists, who were clearly disposed to dispute many of the statements and their interpretations. However, these papers do present some viewpoints which have to be taken into account in considering how science and technology should be used, and be presented, as tools for development.

Science and Technology on Trial

JUDITH WRIGHT
Poet, Conservationalist

'To accept as a fact of life that a certain technology will be used, for the simple reason that we know how to use it, or that we shall continue to live under a certain social system after it has become too complicated for human understanding, is tantamount to an abdication of intellectual and social responsibility. Fortunately, the likelihood that this kind of abdication will continue much longer is not warranted by historical precedents.' (Rene Dubos: A God Within, p216.)

'Wherever one looks, one sees this problem of institutional rigidity in the face of technological change.' (Michael Shanks: The benefits and social costs of growth, in Can we survive our Future, ed. Urban, p175)

'We all live in Pennsylvania.' (Chant of European street marchers).

The technological determinism that Professor Jevons deplores and which Rene Dubos condemns as an abdication of intellectual and social responsibility still seems to rule not only many laymen in their view of what can be done about the world's problems but too many scientists and technologists as well. There have been a great number of publications, over the past decade or two, singling out various aspects of the exponentially mounting troubles that humanity is presenting itself with, through a population which is likely to double within a quarter of a century and an addiction to unbridled consumption of high-technology products, in a situation of looming scarcity. But it is no longer fashionable to pay more than lip-service to the ideas and plans and the sense of urgency which roused the world in the 'sixties and early 'seventies. While there may have been good reason to question some of the more extreme statements of the time, it continues to surprise the more naive of us that the problems outlined at the first Stockholm conference on the environment in 1972 have apparently sunk below the horizon, that practically nothing came of that initiative, and that the United Nations can now organise a conference whose title assumes that development (a dirty word in 1972) is what science and technology, and hence humanity, is all about. Dr Millington's paper recalls those problems - but it is essentially a plea for more research into their present effects and likely future impact. That in itself emphasises that the pendulum of scientific, technological and industrial interest and funding has swung far since 1972.

Since then, we have of course seen plenty of disasters - tanker wrecks have despoiled beaches and fishing-grounds, chemical works have exploded spreading poisons, the effects of the Green Revolution have been socially damnable, and so on. It might be thought that research and technology would by now have altered their objectives to some extent. That on the whole they have not is reflected in the discussion papers. Problems of quantifying the economic, social and physical effects of our present impacts on the biosphere, problems of laying down parameters for research, problems of convincing Governments and funding bodies of the need for and hence, above all, problems of getting money, seem to have slipped into the too-hard, if not the too-late, basket. The general shift in emphasis away from the questions which sprang so dramatically into focus in the recent past may or may not indicate an ostrich-syndrome among scientists and technologists; certainly it indicates an unwillingness on the part of the funding sources to finance the kind of research Dr Millington speaks of. For great is the power of the immediate dollar-nexus, pollution-control and the EIS and the rest are dollar-consuming and unprofitable as well as inconvenient, and on the whole scientists are now content to be quiet. As a Russian poet wrote (I quote a translation), 'We are not made to survive, alas, but to step on the gas.'

That piece of technological determinism on the part of a poet is not typical, though. Not all of us are willing to abdicate our futures so easily. It is worth commenting that few of the discussion papers which deal with the application and/or transfer of technology seem to note the existence of people as a factor which might throw disorder into the smoothly functioning actions and reactions of Governments, industrialists and organisations concerned in the process. For instance, the information flow through the Sabato triangle moves between and among governmental decision-makers, scientific and technological research resources, and 'the productive sector', the appliers of the scientific and technological output. Its consumers seem to be assumed as a neutral or consenting mass, open mouthed for the benefits and unlikely to protest at the disbenefits they are about to receive. The recent example of Iran seems to indicate that, even in the Third World, the consumer is no longer as passive as before, while in Europe and the United States protest against the nuclear industry is now so strong that it seems that - given time and much further provocation - not even the most drastic laws and police action might stop a real takeover.

Surely it is time that scientists and technologists began to consider people as something more than passive consumers or, alternatively, inexperienced meddlers in what they do not understand. The problem does get a mention when Mr Peres glances briefly at the fact that corporate bodies, whose activities are becoming controversial, are 'seeking the protection of the political system' against the scrutiny, criticism and protest of various community groups. There is no hint that this runnning to 'mother' for protection against the hooligans in the streets is anything but justified.

Yet this collaboration between Governments and corporate bodies is certainly dangerous. Governments are already armed with draconian powers in the case of protesters against nuclear industry; often they themselves have close ties with the interests that the corporate bodies represent. They may even stand to profit from them, as in the case of the uranium industry here. Meanwhile the community groups - which are after all part of the electorate which Governments are supposed to represent and whose interests they are supposed to protect - and indeed the community at large, becomes increasingly cynical and alienated. There is plenty of explosive material lying around for the spark, and plenty of sources of possible future confrontations exist. The social disruptions to which Professor Hill points, as we move from the industrial full-employment age to the age of microprocessing technology, will certainly be much more violent and hard to handle if people already distrust and dislike their Governments, and Governments fear their people.

It may or may not be true that there is an inherent momentum, if not an internal determinism, within an industry-oriented science and technology, which, is, as Professor Jevons puts it, 'running away with us'. But no amount of soothing assurance that we can change direction whenever we like will convince those who no longer feel confident that there is a bit in the horse's mouth and the reins are communicating with it. For the question of who 'we' are is crucial here. The 'little people', the riff-raff who come out against nuclear power or freeways or whatever, do so because they are first to suffer discomfort and the last to profit by technological benefits, but also because of a real conviction that unless they do, the message will not get through. They have little illusion that they are represented among the final decision-makers.

Therefore Professor Hill's paper, with its wistful glimpse of a possible future in which the 'portable mechanical mind' might free us into a new and more humanely-based community life, a steady-state conserving society in which our long-stifled creativity might awaken, implies an urgent need for *people* to be actively informed and involved from the beginning. He points also, implicitly at least, to the need for humanising the great multi-national and other corporations which at present control and monopolise, as well as profit by, the distribution of technology. But these bodies, which will also own the 'bunched innovations' which will be needed if the transition is to come about, are not human and not flexible. As institutions, they are designed to be self perpetuating, self protective, and in command of their resource-base. The steady-state conserving community has nothing to offer them, for their existence depends on continuing and increasing profit. They will therefore not dismantle themselves at the command of Governments - supposing that any Government dared to give such a command. Maybe they are already too tall for us to reach their foreheads with a mark of death.

Nevertheless, there are other possibilities, and they reside in people and in people alone. As Rene Dubos points out, in a continuation of the quotation at the head of this paper, men have historically repeatedly rejected the ways of their predecessors, and most often they have done so in order to, as Dubos puts it, 'exorcise the occult demonic forces that were in the process of dehumanising life'. Occult and demonic or not, life nowadays in the industrial city is getting dehumanised enough to set off a silent revolt - the simple revolt of leaving. Small commune or family farms, craftsmen's colonies, permaculture enthusiasts and more esoteric groups of cultists now dot the countryside. This is not a practical way of solving the city's problems, but if it were taken far enough, it would leave the shell of the industrial corporation and the social machine standing empty to crumble from within. Even without actual physical desertion, a simple psychological desertion or withdrawal could also undermine those rigid institutions which rule our lives. It is a kind of vote against urban industrialisation and all it implies - and, I might add, against the attitude which regards people as no more than a workforce or a consuming mass. Rising unemployment is likely to confirm, rather than contradict, this sense of alienation from, and indifference to, the great machine.

Finally, I wish I could see in more of the discussion papers an awareness of the problems of people. Most of them seem to start from the assumption that science and technology are naturally in the service of the big - the big Government, the big corporation, big capital and big organisations. If scientists and technologists are too closely allied with the seats of power, the small faith we have left in their goodwill and capacity to solve our predicaments will collapse. People, however, are going to be a lot more important to the continuation of science and technology in the future than they have ever been. Fallible, feckless, prejudiced and unreliable as people are, their understanding and cooperation are going to be essential if that more humane steady-state conserving society of the micro-processing age is ever to come about. I wish I could see more signs that, as the big changes sweep over us all, science, technology and people will come together in a rapprochement, rather than a confrontation or a mere mutual apathy.

To this end, I would suggest that, before it is too late, the Sabato triangle should be expanded at least into a rectangle, if not a circle. One first step could be for scientists and technologists to recognise and acknowledge the rights and the concerns of those community groups which are causing the corporations such anxiety. At present, with honorable exceptions, the scientists and technologists tend to steer very clear not only of involvement but of contact on any terms. A further drift towards polarisation could put a disastrous distance between people and those who carry out the research and applications of a science and technology which ordinary people begin to perceive as at best risky, at worst leading to final disaster. The chant of the marchers in Europe is symbolically, if not factually, true: we do all live in Pennsylvania. That is, we live on the far frontier of vast world-wide experiments, chemical and physical, which are being carried out not in the laboratory but in the world itself, and whose subjects are ourselves.

ANN FORWARD
Vice Federal President
Administrative and Clerical Officers' Association

Technological change is a change in the way in which work is done. It follows that perhaps its greatest impact is on the people who work. The trade union movement accordingly has a great interest and involvement in the introduction of new technologies to the work place. One of the most difficult functions the unions have is to fully comprehend the likely impact of technological change and to devise appropriate responses to it. In this regard, employers, academics and Governments in this country have, in my view, abdicated their responsibilities in relation to informing and consulting workers and their organisations, the trade unions. The cloak of secrecy and partial information which surrounds the management of technological change is responsible for a great scepticism, even suspicion, among trade unionists.

Unions have no option but to achnowledge the existence of the current microprocessor revolution. It is here, and the philosophy of the Luddites is not a realistic response to it. However, it is my view that unions must insist on their members, the Australian work force, having a greater influence, if not a determining influence, over what happens to their lives. The evidence available to us is that new technology causes great disruption in people's working lives and, despite management assertions to the contrary, that it causes a loss of jobs. It is acknowledged that there will be some new jobs created in order to use the new machinery. These will, however, be fewer in number than the jobs which are lost. A net reduction in the number of jobs means increased unemployment. To argue that new technology creates jobs is to attempt to mislead people into not resisting it until it is too late to change the outcome - job loss. Small wonder that there is great suspicion, perhaps even complete distrust, of management pronouncements about new technology. We are told half-truths about its effects, and even less about the real objectives of its introduction.

There is a belief in some unions, for instance, that Telecom Australia, aided and abetted by the Federal Government, is using aspects of technological change as a vehicle for selling out not only the jobs of highly skilled Australian workers but also Australian sovereignty over its communications system. Telecom has recently advised of a new policy which in effect gives sole access to the PABX (private automatic branch exchange) market to private suppliers, mostly overseas-based. We believe Telecom has begun a process which will result in its vacating all but its switching functions, causing, *inter alia*, massive redundancies in the Telecom work force. This view is supported by the shameless bias of the White Paper on a domestic satellite, which indicates the concern of the Government to assist IBM at the expense not only of Australian workers but of Australian control of its own communications system.

The need for workers to be meaningfully consulted, at least through their unions, is widely acknowledged. Perhaps it is more true to say it is acknowledged in the public sector, as evidence is available that in some industries private employer organisations are advising their members to refuse the unions a role in the decisions about the introduction of computer technology. But in the public sector, we have recently seen the spectacle of the then Minister for Employment and Industrial Relations boasting of his Government's consultative industrial relations policy at the ILO. The reality is very different. Let me give you an example involving the Mandata system, the system being installed by the Australian Government for keeping and processing personal data relating to its own employees, Commonwealth public servants. The once-esteemed Public Service Board, contrary to an earlier understanding with the unions, has refused to make the report of an impact study recently conducted in relation to Mandata available to unions. Public service unions believe that perhaps 1500 jobs are jeopardised by Mandata. The Board has detailed information as a result of its impact study, but it will not make this vital information available to the relevant unions. The argument is that we can have 'a document' after the Board has interpreted, ie fiddled with, the data it has obtained. 'Facts are facts' we were told, and there's only one way to interpret them, so we should trust the Public Service Board. On the contrary, however, we believe the Board to be withholding damaging information, at least until it is too late for it to be included in any one of a number of submissions to the Myers inquiry into technological change, the deadline for which is May 31.

Under circumstances like these, no result can be expected other than distrust and hostility. The impression is created that the stated purposes of introducing new technology, purposes related to efficiency and productivity, are at best secondary to an unstated purpose. The maintenance of existing power relations, or worse, the accretion of greater power to the ruling class is, if not the purpose, at least an intended outcome of introducing computer-based technology.

It is nonsense to argue, as some do, that technology is value free. Scientific knowledge may be value free, but the technology based on that knowledge is not. It is a widely held view in the trade union movement that technology is being developed which will, by design, demean the value of human labour by deskilling jobs, or by removing them entirely from the labour market, not to mention the disruption of the lives of those who retain jobs of some sort. It is not inevitable that technology should be of this nature. It could, for instance, be developed in such a way that scientific knowledge is applied to the real problems of mankind around the world. I do not believe it is really beyond the wit of the scientific and technological fraternity to apply a different set of values to scientific knowledge so that technology is developed which has a positive social value. I see as negative the current exacerbation of class divisions created by depriving an increasing proportion of the community of adequate incomes and producing goods for an increasingly elite market. The imposition of a technology having such divisive underlying values represents a form of imperialism which deserves to be rejected. If democratic principles were part of the thinking of those who make development decisions, technologies might have been, and might yet be, developed which are seen as more acceptable and more appropriate to the needs of the communities in which they are intended to be used. If motivation were not profit but human and social wellbeing, we might, or even would, have different, less disruptive and more worthwhile technologies.

In brief, I am arguing from a trade union perspective that professional and academic research and development personnel should be more conscious of the implications of the value systems built into their work. Such people have no divine right to make decisions which result in perhaps 30% unemployment and which will certainly alter the day-to-day lives of the entire population at home and at work. There is a very real need for some accountability of people engaged in research and development work to those who have to live with the results, and I do not refer to the suppliers of research funds. The need is for accountability to society, not to the elites with economic and political power to protect.

The application of democratic principles to the various aspects of technological change would be a difficult task. But if we are to avoid the evils of technological determinism and research for the sake of research, and retain the vital elements of human and social choice, it is a task which I believe should be undertaken. Not only should workers and their unions be involved in making decisions about the nature and timing of technological change but they should also be involved in decisions about the distribution of the advantages and disadvantages of it. I believe such an approach would also encourage the development of technologies which have the very desirable attribute of being socially appropriate to the communities in which they are to be applied.

SENATOR SUSAN RYAN
Shadow Minister for the Media and Communications

It is appropriate that Australian scientists and technologists should gather to consider the role of science and technology in development. Amongst Western nations, European Australia is unique, for its development and growth post-dates the upsurge in invention and innovation which formed the classic industrial revolution of the late 18th and early 19th centuries. The application of the basic technologies of that revolution, allied to the increased understanding of our environment that came with the growth in the physical sciences, brought basic solutions to the developmental problems which confronted 19th century Australians.

Coal, steam and iron, wrought into railways and steamships, broached the tyranny of distance which limited growth. The completion of the electric telegraph, in 1871, made Australia as accessible to the London capital market as Birmingham or Manchester. Refinements of these technologies allowed further development in the early 20th century. Advances in public health and solution to problems of water supply, sewage disposal and transport encouraged rapid urbanisation in that period and gave Australia the character that we know today; a highly urbanised society resting, at times precariously, on the uncertain wealth of the rural sector and the protected fortunes of a small, and often inefficient, manufacturing industry.

The technology which has underpinned our development has been largely imported, with little domestic research and development other than that necessary to adapt British, European or North American technologies to Australian conditions. That pattern of dependence remains today, with much of our technology being imported and scientific research and development mirroring that now occurring in other advanced industrialised countries. It must be asked whether a large part of that research and development effort is appropriate to the problems which confront Australia in the late 20th century.

The problems might be identified as social problems; those of health, poverty, discrimination and unemployment. Their solution lies in the rational and appropriate use of science and technology within our society. How appropriate is much spectacular medical research or development whilst basic problems of diet and public health remain largely ingored? What of cancer research whilst the problems of widely used carcinogenics remains unresolved? Are the real needs of energy and resource conservation attracting the monies and attention necessary? It might well be deemed impertinent for an elected politician to question the competence of scientists and technologists to determine their priorities, or to express misgivings about the solutions which they propose. Scientists and technologists, each expert in their own field, may view themselves as the only section of our community with the ability to decide what is an appropriate solution to the problems which confront us. If this is the case, then we are presented with a very real threat to the democratic process in our society. There is a danger that a scientific oligarchy impervious to public comment, and unresponsive to popular opinion, will make the decisions which determine our social futures.

There is no better example of how this oligarchy functions than in the present debate about nuclear energy. In the Harrisburg incident the accident that nuclear engineers assured us could not happen, almost occurred. The nuclear industry, which embraces private enterprise, government agencies and tertiary institutions, has met public concern and dismay with an unparalleled arrogance. To them, Harrisburg was not a disaster but vindictation that the safeguards built into nuclear reactors really work. It is a little like claiming that the sinking of the Titanic proved that some of the lifeboats worked.

Nuclear energy is perhaps the most extreme example of science and technology pushed to its furthest limits, with minimal risks acknowledged but which it is claimed are outweighed by the social good derived from nuclear power. There are many other instances where technology in common use is neither fully understood or controllable. The industrial world is dependent upon the carriage of most of its oil, its basic energy source, in very large carriers, oil tankers, the structural behavior of which, in heavy seas, no engineer or technologist can predict. The increasing incidence of oil tanker disasters is testimony to a technology which fails to observe its environmental context.

Are scientists and technologists engaged in a conspiracy which threatens our future? Of course not. Yet there is clear evidence that scientific research and technological development often fail to consider the social and environmental impacts which they may have. Is this the fault of the indivudual scientist or is it symptomatic of a malaise not only within the scientific community but within society generally? Without defined goals of social welfare and development to guide research, it would be unreasonable to expect that the individual scientist or technologist would have a composite picture of where science ought take us.

The Government, in setting up a permanent Australian Science and Technology Council (ASTEC), has recognised the need for an overview which will allow research priorities to be set. Ideally, such an overview should encourage the optimal use of the scientific and technical resources available for social welfare objectives which will benefit all Australians, and perhaps the developing nations. But the composition of that Council, and its recommendations in its recent report to the Prime Minister, suggest that all we are to see is a self-fulfilling quest for research objectives which industry and the scientific community themselves deem to be important. Recommendations are ordered by either four, three, two or one star - four stars denoting 'high priority', for urgent action, whilst one star means 'recommended'.

Given the theme and purpose of this Workshop, to assist preparations for the United Nations Conference on Science and Technology for Development to be held in Vienna later this year, it is rather disappointing to note ASTEC's recommentation 37.

This recommendation, 'That recent initiatives involving government departments and agencies, Australian industry and tertiary education institutions in aid programs be encouraged and expanded and that continued support be given to Australian involvement in the Association for Science Cooperation in Asia', attracts only one star. The need for increased research and development activity in marine sciences and technologies has been recommended for the highest priority, recognising the vast mineral wealth that now lies within our 200-mile ocean zone. Environmental matters are not given the same urgency and although the pressing problem of lack of liquid fuels is recognised, proposed areas of research and development are a little questionable. If the technological solution to that energy shortfall is conversion of coal into oil, it is worth remembering that it is a technology the economics of which have been compared to making 50-cent pieces on a fire of dollar bills.

Implicit in that comment is my belief that there are non-social technologies which, by their very nature, distort social relationships and prevent social welfare goals being realised. Nuclear energy must be to the fore amongst these, but there is an array of technology which must be reviewed to determine its true social utility. I would suggest that technology is not socially or politically passive, just as science is not ethnically neutral. The act of questioning technological change will lay me open to a range of charges. Foremost amongst these will be cries of 'Luddite', a term that has gained new currency as we enter the age of a second industrial or technological revolution. Luddites engaged in smashing the technology which displaced their labour and disrupted the social order based upon rural cottage industry. We are now faced with even greater social and political disruption, as new technologies, particularly those based on computers and micro-chips, make inroads into 'traditional' work patterns and forms of employment.

Without engaging in a debate about the appropriateness of the Luddites' response, if the term is now used to denote someone opposed to ill-considered or unbridled technological change, then I will accept it. Indeed, it might be fitting that European Australia, borne in the post-Luddite age, should at last question the ethic that technological change is always socially desirable and inevitable. I have said that technology is neither socially nor politically passive, and this might lead to a further charge - that of technological determinist. Technological determinism does not mean simply the belief that technologies have some independent inner dynamic that shapes and determines the form of society. Dogged technological determinism conveniently disguises the central role which human intellect and ingenuity plays in the development and deployment of technology.

It is that human element, and involvement in technological change and scientific development, which demands that technologies must be social. A technology is a manifestation of our interaction with the environment, the world within which we live. Around the technology flows the relationships and interactions which compose human existence. It is in one of my areas of responsibility as a Shadow Minister, the media and communications, that I fear the greatest potential for the use of non-social technology exists.

The media/communications technologies have an inherent capability for social use, for education or entertainment, but for political and economic reasons that capacity is not being realised. We are now witnessing the introduction of new technologies throughout the media/communications industry. Computerised typesetting has 'revolutionised' newspaper production, teletext promises an electronic newspaper in every home, and hand mail will be displaced by fascimile transmission of letters. And in Australia, we now await a Government decision on a system which will optimise the use of all of these computer and microprocessor-based technologies, a national communications satellite.

A national satellite system is a case study in our present inability to fully assess the impacts which technology will have socially, politically or economically. The way in which the decision is being made is indicative of the threat to democratic decision-making which high technologies represent. The debate has been couched in technical jargon which is obscure to the lay person. It is a debate about 'transponder wattage' and 'antenna size', but it is left to the electronics experts. But the decision will have impacts far beyond the ability of those experts to assess. Their preoccupation with technical excellence or the mechanical correctness of the system precludes consideration of social and political impacts. That is not their fault, but the product of a political system in which the worth of a project is measured in narrow accounting terms of superior economic performance. And it is in the narrowness of our society's definition of worth that I would suggest the central problem with science and technology lies.

Priorities in scientific development and technological innovation are determined not by a wide-ranging process of social accounting but often solely by economic measurement. Continued technological change has become central to continued economic growth. Planned obsolescence was the 1930s answer to depression and unemployment; technologically induced obsolescence has now brought Western economies full circle back to those problems of unemployment and under-employment.

If science and technology are to be harnessed to realise the goals of social welfare which [illegible]atic societies pursue, then they must be placed within a broad social and political context. Social and political goals should determine where resources are applied, rather than the mere technical feasibility of a project. Too often, it would seem that it is the 'autonomy' of technology which is the greatest obstacle to its being used beneficially. An end to that 'autonomy' does not mean curtailment of academic freedom or limits to individual inquiry. It ought to mean an overall national policy decided by Government, the scientific community and society at large which ensures that science and technology meets the real needs of the Australian people.

Science and Technology on Trial

BRIAN NOAKES
Director
National Employers' Industrial Council

The approach that I have adopted in this contribution to the debate is to attempt to set out what seem to me to be some of the major issues which are implicit in the question: how can science and technology solve the problems of development in this country? And also, to comment on the treatment, or non-treatment, of those issues in the various papers prepared for the Workshop.

The first major issue to which I want to draw attention is the need, as I see it, for a more informed public debate about the processes of scientific and technological change. Most of the discussions taking place in the community on this issue are based on emotion rather than reason, and on a fear of the unknown, which is fed by the present relatively high levels of unemployment. What needs to be understood more widely, in my view, is that changes in science and technology are not new; that the process of change is not a new thing and has been going on for a very long time, and that, in general terms, it has brought great benefits to mankind. In this respect, it is not said often enough and clearly enough that change of this nature has vastly enriched our lives, and has released us from physically and mentally onerous tasks, amongst many other things. Our failure to make these points has led to the benefits of change being taken for granted, and to, in many quarters, a single-minded concentration on what are seen to be the undesirable consequences of change.

It is therefore disappointing to find in the papers presented to the Workshop, no defence of scientific and technological change, no analysis of its benefits, but instead a preoccupation with its presumed adverse social effects. And I must say that one of the benefits of this discussion tonight is that at least some scientists have been smoked out to defend scientific and technological change. Oddly enough, in the papers which deal with this issue, little hard evidence is presented to justify what are said to be the adverse effects of change and their concern seems to be rather with what might happen in the future, rather than what has happened or what is happening now.

The second and related major issue as I see it, is the impact of scientific and technological change on work opportunities. In this respect, the process of change does two things: it changes the method of production so as to change the structure of the labour force; and it changes the nature of products, and thus the demand for products. Two questions then arise. Firstly, how is labour to be used efficiently during the course of change. Secondly, what is to be done with labour that is displaced because of change. Those two questions cannot be answered in isolation. They must be examined as part of society's plan for dealing with all social changes which are occurring in the community. In particular, they must be dealt with against a background of the community's overall policy and attitude in relation to labour and unemployment. It is fair to say, I believe, that Governments in this country, irrespective of their political philosophies, and indeed the whole community, have been committed to the concept of full employment. But it is unfair to suggest that that goal has changed, even with the significant increase in unemployment over the past few years. Certainly, I do not believe that anyone in this country sees any benefit to be achieved by maintaining high levels of unemployment. On the contrary, I think most people understand the social and economic dangers that are inherent in letting that situation drift. But there must be a willingness on the part of everybody to try to accommodate change, and to try to take advantage of improvements in methods and techniques which enable increased production and increased productivity. For instance, if we don't take advantage of technical progress, our competitive position with other countries which are taking advantage of change will decline further, and we will continue to suffer the problems of a high cost structure relative to our trading partners. In those circumstances, we may not only be unable to improve our living standards but we may well find it difficult to maintain our present standards.

There cannot be any doubt that the only source from which improved living standards can be obtained is from increased productive capacity and productivity of the community as a whole. If we accept that fact, then I suggest we must also accept the fact that we have to abandon the old-time belief that a particular worker has a particular right to a particular job for all time. That concept, however good it was in the past, and however well it may have served past generations, is alien to the achievement and maintenance of full employment in a changing society which must depend on a highly flexible, adaptable and mobile labour force. The position simply is that changes of employment will become necessary and inevitable, and we cannot stop them. I don't believe that the changes should take place in an arbitrary fashion, as was suggested by Miss Forward to be the employers' view. Steps can, and should, be taken to lessen the inconvenience and dislocation that come about because of change. Indeed, with proper planning, the incidences of unemployment resulting from changes in methods can, I believe, be considerably reduced, and in some cases avoided completely. We need, however, to take that concept a little bit further. In my view, if a person has a period of unemployment which is occasioned by change in methods of production, the whole burden of that unemployment shouldn't fall upon him or upon the industry which is being affected by change. Accordingly, when you look at change in that context, we ought to be looking not at how we can keep people in particular fields of employment but how we can assist them to move effectively from areas where they are not required to areas where they are required. At the same time, we should be examining ways and means of ensuring that people are not left to their own devices without assistance from the community for any of the time in which they are unable to be employed. We also need to ensure that they have the opportunity of retraining and to be supported while they are undergoing retraining. Again, I must say that I find it disappointing that papers that deal with this issue of the effect of change on work opportunities tend to concentrate on the sensational aspect of what the newspapers have chosen to call the 'computer haulocaust' and what has been called tonight the microprocessor revolution. There is, so far as I am aware, little or no evidence that the computer and the microprocessor have resulted in significant unemployment in this country, or that they will do so in the future.

The third major issue for consideration is, I believe, the implications for the impact of scientific and technological change of changes in our population growth rate, in the age structure of our population, and in the labour force participation rate. For example, the slower rate of population increase, to which the Borrie Report drew attention, will have a substantial impact on all areas of economic and social activity. In particular, it will have an effect on social institutions, industrial relations, economic activity and the demands of the community for services. It is, I believe, essential that we should attempt to acquire an appreciation and understanding of its full implications. Similarly, the reduced rate at which young people enter the work force has important implications for many of the areas to which I have referred. Consideration must also be given to the consequences which will result from the ageing of the population. With a greater proportion of the population in the older age bracket, it can be expected that the composition of the labour force will experience a similar shift. That will raise questions about the restructuring of jobs to cater for different physical capabilities, and about the retraining of older workers to cope with the effects of change. It will also raise significant issues concerning the financing of social services to cater for a larger retired sector of the population. Another important issue, in that context, is the effect on employment opportunities of higher labour force participation rates, in particular as they relate to women, and even more particularly as they relate to married women. None of those questions have, so far as I can see, been raised by the papers presented for the Workshop.

A further important issue is that of education and training to cope with the effects of scientific and technological change. The experience of industry in this country indicates that there is a growing gap between the education supplied at the secondary level and that required to undertake the increasing range of technical and skilled occupations available in industry, where there is a need to have a higher level of technical knowledge. People entering the work force with a secondary school education of the type now generally available are, in fact, ill prepared to take their place in today's technically oriented industries. The education required for industry today must have a higher vocational bias. Even today, with current levels of unemployment, there are many sectors of industry unable to secure skilled manpower. Throughout the 1950s and the 1960s our system of training skilled workers failed to meet the demands of industry, and we met our needs largely through immigration. That supply has now been substantially restricted and the strains on our own training systems, particularly the apprenticeship system, have increased substantially. It now seems to be reasonably clear that, unless changes are made, our institutions will not be able to cope effectively with these additional demands, and the possibilities of continuing to cope with the process of change will be open to question.

Several of the papers presented to the Workshop deal with the question of education and training, but as I see it, they, perhaps understandably, have a bias towards scientists and technologists and take a narrower view than that I have just presented. In this respect, we have in the past tended to believe that education and training were only appropriate to young people, and we structured the system of education and training to cater primarily for that group. But, with the anticipated decline in the youth population relative to the adult population, to which I have referred, much greater emphasis will need to be placed on recurrent adult training and recurrent adult education to enable these people to acquire and update labour-force skills to meet the changing technological demands of industry.

These are some of the issues to which I believe we must direct our attention, and to the resolution of which I believe scientists can make a significant contribution. I should say, so that I do not leave a false impression, that I found the papers which were prepared for the Workshop to be stimulating and thought provoking. In some cases I have a positive disagreement with their line of argument, with their use of material and with the conclusions which have been drawn. But, overall, I think they represent an important contribution to what will undoubtedly be an ongoing debate on a subject of critical importance in our community.

JOHN BIRCH
Australian Council for Overseas Aid

The decade of the 'seventies has seen a growing acceptance that the concepts which guided aid and development in the past decade are outmoded. Despite growth in many Third World economies, millions still live below the poverty line.

The Second Asian Agricultural Survey found last year that in the countries surveyed

- the food situation was much worse than a decade before,
- rural poverty had considerably worsened and had been aggravated by increasing inequalities of income, and
- new technology had done nothing to curb the growing number of landless labourers.

The fond hope that economic growth at the national level would in time 'trickle down' to the needy masses has by and large not been realised.

According to the Overseas Development Council, 'the costs to the poorest 40% of the population in many countries that followed this 'trickle down' strategy have now become clear. Not only have the relative incomes of this group declined, considerable evidence even suggests that the absolute income of the bottom 10-20% may have fallen'. Instead of a 'trickle down', there was in fact a 'sucking-up effect', resulting in a more skewed income distribution.

The failure of the 'trickle down' approach has led to the reassessment of development policy alternatives and the emergence of a basic needs concept. Here, emphasis is placed on directly meeting people's basic needs for food, water, health care, education and employment. Implicit in the basic needs policy is the participation of people in making the decisions which affect them, through organisations of their choice.

What contribution has science and technology made to development in less developed countries?

In 1971, the UN published the World Plan of Action for the application of science and technology to development. It was based on the premise that the scientific approach offered the best hope for assisting developing nations to speed up the process of their all-round development. The World Plan saw the need for greater investment of resources in scientific and technological research and the transfer of modern technology to developing countries. It saw the main obstacles as a lack of trained manpower and institutions in developing countries and the scientific isolation of those countries.

Science and Technology on Trial

The UNCSTD Conference has provided a focus for criticism of many of the ideas embodied in the 1971 World Plan of Action.

The traditional view of science as universally available knowledge supported the assumption that Western-style industrial development was appropriate for developing countries. It was anticipated that eventually the world would be transformed into a sort of Western-style technological monoculture. This 'international republic of science' has encouraged science in developing countries to be oriented towards Western scientific communities, rather than to the indigenous requirements of their own society.

As a result, most Third World science and technology bears little upon the problems of the very poor, and most scientists and technologists go along with that. They tend to enjoy rather low social prestige (unlike, say, lawyers), so they turn to the world of international science to get their standing. They go for prestige subjects that will (or at least may) lead to international recognition. Traditional technology and the needs of the poor seldom involve such subjects. The Director-General of the Indian Council of Medical Research recently drew attention to the fact that whilst he had dozens of project proposals to study problems related to cancer, a major afflication in the West but only a minor one in India, there were only two project proposals related to leprosy, a major disease in India.

Similarly, this orientation towards Western science and technology has resulted in massive importation of technology and consequent under-utilisation of local research capacities.

Again, let us take an example from India. It is a country with the third largest body of scientists and technologists in the world, behind only the USA and USSR, and, in terms of gross output, one of the ten largest industrial countries in the world. Yet, because of pressure from foreign oil companies in the 1960s, India developed a State-controlled fertiliser industry based on imported naptha as the feedstock, rather than using local coal supplies (as in China). India is now paying a heavy price for that decision with the increase in petroleum prices.

The approach that treats knowledge as a commodity and concentrates on attempts to facilitate its international flow also has limitations. The Science Policy Research Unit at the University of Sussex has shown that less than 1% of the total research effort of the developed countries has any significance for the developing world. Under such circumstances involvement in Western scientific communications systems only distracts scientists in developing countries from local problems. What has become recognised is that the problem is not to transfer technology but to transform it. This has resulted in the development of appropriate technologies.

In recent years, we have seen a rash of institutes and organisations established to invent and produce a range of gadgets (eg solar cookers, vertical axis windmills, bio-gas plants) that have been produced with great enthusiasm but little success. One reason for this lack of success is that 'appropriate technology' products are rarely thoroughly tested and evaluated. This is not surprising when we realise that in 1976 the OECD estimated that only $5 million was spent on appropriate technology research and development, as against $60 billion on conventional technology. For example, a methane bio-gas plant developed by the Planning Research and Action Institute in Lucknow failed because the conversion efficiency of the plant was only half that of the pilot plant due to operating temperatures being 10°C lower than expected. However, most appropriate technology has failed for social rather than technical reasons. For example, a solar water pump developed for a Mauretanean village in the Sahara failed because of the feudal power structure of the society. As soon as the technical experts departed, the two richest men in the village occupied the plant and sold its water to the people, who were than poorer than before.

However, the greatest difficulty for appropriate technology is that few societies give sufficient priority to the social organisation and life-styles that foster appropriate technology. This applies as much to rich societies as to the poor. The traditional processing of food by drying meat or fish or processing tempe and tahu from soya bean so they can be stored without refrigeration or cooking is being increasingly replaced by more sophisticated and energy-consuming food processes. They are promoted as modern, and therefore necessary. Similarly, in our society, our most effective solar device, the clothes hoist, is being replaced by electric-powered drying cabinets.

One view that is developing in many Third World countries is that the very nature of Western science and technology is such that its continuing use will result in a continuing dependence. Arising out of this view are proposals for isolation from Western science. These attitudes are encouraged by the disappointments of the Third World countries of not having achieved a new international economic order. They see science and technology as part of the exploitative relationship that exists between developed and developing countries. In addition, there are those within the developed countries who see Western science and technology as a major factor in a life-style based on an insatiable demand for consumer goods that imposes increasing demands on the natural resources of all the world.

It is suggested that a change in life-style towards a more conserving society would demonstrate to the less-developed countries that we are serious about sharing the earth's resources more equitably. What is needed, then, is a change in the values of the world scientific community such that development would be the substantive goal of science policy of the industrial world.

If UNCSTD is to have any real and lasting achievement and science is to make any significant contribution to the eradication of world poverty, it will come about from the integration of science and technology into broad development objectives.

In the USA, Dr Frederick Seitz, a former president of the National Academy of Sciences, has established a Council for Science and Technology for Development. The aim of this Council will be to attempt to integrate American science and technology with the problems of the less-developed countries. I commend a similar activity to these Academies as a follow-up activity to the UNCSTD Conference.

SCIENCE AND TECHNOLOGY - FOR WHAT PURPOSE?

WORKSHOP SUMMARY

BY

J.G. CRAWFORD

Sir John Crawford, Kt.cr., CBE, MEc.Syd., LLD ANU, Order of the Sacred Treasure, 1st Class, Japan, FASSA, the Chancellor of the Australian National University, has long been associated with economic development, both nationally and internationally. He is Chairman of the Board of the International Food Policy Research Institute in Washington, a member of the Board of the International Fertilizer Development Centre, Governor of the Canadian International Development Research Centre (IDRC) and Chairman of the Consultative Committee on Research Development (CCRD). Sir John was a member of the World Bank Economic Mission to India (1964-65) and Vice-Chairman of the Commonwealth Committee of Economic Engineering (1962-64). He was Chairman of the Technical Advisory Committee to the Consultative Group on International Agricultural Research (CGIAR) from 1971 to 1976. He became the first Chairman of the Australian Wool Industry Conference in 1962 and was President of ANZAAS in 1967-68. He conducted the Commission to Advise on Assistance to Industries in 1973 and was recently Chairman of the Study Group on Structural Adjustment.

Sir John received his tertiary training at Sydney University and was Walter and Eliza Hall Research Fellow (Econ.), in 1932-33. He became Director of the Bureau of Agricultural Economics in 1945, was Permanent Secretary of the Department of Commerce and Agriculture from 1950 to 1956 and of the Department of Trade from 1956 to 1960. He was Director of the Research School of Pacific Studies at ANU from 1960 to 1967 and was Chancellor of the University of Papua New Guinea from 1972 to 1975.

I did not have time to consult the mathematicians on the art of summing the unsummable. Accordingly, I can only suggest that for a summary you re-read all the abstracts! For my part, I will be content to draw attention to what seemed to me be be some major issues and conclusions arising from the papers and the discussions.

The points I have selected all arose in the discussion, but their treatment necessarily reflects some ideas of my own, not offered from the floor. The points are:

1. Too much must not be expected of the Vienna Conference.

2. Two or three aspects of the Australian scene - ASTEC, growing fear of 'technology', and a recognition that we are only just beginning to see that government-led research/technology is, or can be, a continuous process in secondary industry as it has long been in primary industry.

3. An acceptance of, but some elaboration on, Professor's Jarrett's remarks on development (especially for the developing world).

4. A major point of significance to the three Academies (Social Sciences, Science and Technological Sciences), suggesting that research is not fulfilled unless the technology evolving from it is seen as one basic component only in a very complex set of policy action. My illustration is agricultural, and a brief hint of it is in Evans' paper.

5. In the course of this last point I will refer to some aspects of transferability of science and technology, including the need to recognise that training is a necessary part of any effort to offer cooperative assistance in these matters to less-developed countries.

These five points will strain my 30 minutes and must be made in staccato fashion. This I regret, but I accept the constraint.

POINT 1

Perhaps it is unnecessary to say that the Vienna Conference will produce marked political divisions, many resolutions and some practical gestures. People like Guy Gresford will secure the construction elements, but the politics of the Third World are even less solidly homogeneous than those of the First World and in this there is hope. The truth is that much more realism is shown in bilateral relations (development assistance programs), in multilateral relations represented by, for example, the United Nations Development Program (UNDP) and the World Bank, and in special activities such as the Consultative Group in International Agricultural Reseach. It is through all these channels that relations in science and technology are more likely to be fruitful, and these are the avenues where the positive results of Vienna will be reflected.

POINT 2

I found all the papers dealing with the Australian scene of great interest and value. I only wish I had had them last year before the completion of the report on structural adjustment. I offer only two comments:

(a) We are fortunate that the political process has produced ASTEC, which I believe is already playing a constructive role in Australia. Central to its work is the promotion of an attitude to science and technology which sees them as a continuous process, although not necessarily always, or even purely, the responsibility of those doing the science. I think the successful story of agricultural research is pertinent to the growing realisation that our approach to research related to manufacturing not only needs more resources but more study of the best ways of going about it. The papers have not discouraged me from thinking that a Government/private enterprise partnership in science and technology is both necessary and feasible. ASTEC has a guiding role to play here.

It goes without saying that ASTEC, whether it likes it or not, will have a major role in advising on national priorities in allocation of resources for science and technological development.

A question which is pertinent: will ASTEC recognise that a proportion of research and training resources must - in the national interests - be allocated to cooperative assistance programs in the field of research and technological development in developing countries? To put it quite specifically, over the years I have found it very difficult to get any sanction for individual officers from CSIRO or universities to be released to give some helpful support to a national or international institute. Even more difficult has it been to get funds specially allocated for work of an advanced kind to be done in Austraia in support of work being done elsewhere.

(b) My next point is one of warning. It arises from many papers, but especially from that of Professor Hill.

(i) If the conjunctive of energy shortage and automative processes produce a Kondratiev cycle, we are in for a bad time. I am not fully convinced that we will have one, for economic growth is already evident in a large part of the world. If we can handle trade and the flows of capital sensibly, there is no good reason, to my mind, why we must face a long-term downward trend in economic affairs. However, the fact that the Kondratiev cycle is not a predictive tool does not mean that we ignore its possibilities.

(ii) However, it is not going to be from any public discussion of Kondratiev cycle theory that we will get decisions. We are going to get decisions, possibly negative, from the public and the public attitudes. If the public is becoming uneasy, and even frightened, by 'technological progress' then the Luddite feelings, which are never far below the surface in the community, will have a powerful political sway. On the receiving end of public worry, scientists and technologists are not really distinguishable - all of us are involved in this matter. And I say this despite the evidence of the syndicate which pointed to the net benefit of technological progress. I believe the three Academies and their members have much to offer Professor Myers, as he and his committee examine technological progress and its implications. For my part, I offer sympathy, having already gone on the record as saying that, for economic and social reasons, we have to learn to live with technological change, despite the structural adjustments (including changes in work patterns) which will be required. Perhaps understandably, I pray for the resumption of economic growth, which makes the adjustment process so much easier. But enough!

POINT 3

My next point, which is a link with the problem of transferability, is to suggest that we accept Professor Jarrett's view of development. This is that development now means:

- economic growth (in the sense of rising GDP)
- distribution of growth (the question of equity)

I will, in my next point, elaborate the obvious need for resources and appropriate institutions to support development in both senses; even research requires capital. Here, I do not want to merely confirm what Jarrett said about the difficulty of tackling poverty in the poorest countries (Taiwan, Hong Kong and Korea are not very relevant), but also to express a little more hope perhaps than he did. It is important to be more worried about raising the standards of the poor (urban and rural alike) than about an arithmetical closing of a trend gap. To do so requires a much more direct attack than in the past (via investment resources) in the provision of basic needs (pure water, food, access to medical treatment, access roads, etc) and therefore some priority allocation of economic resources to bring it about. I dislike the term integrated rural development, but the fact is that much off-farm investment is required for employment and for raising the quality of life - at the same offering an increased market to farmers. Encouraging results are being obtained now in several countries. But if you think the whole problem is quickly soluble, let me remind you there are some 586 000 villages in India alone! I am content to make the point with Jarrett that the equity part of the dual definition requires resources directly applied, but that it does enable growth in standards to occur in the poorest areas. It also needs great political determination on the part of national leaders. (I mention in passing that China also has these problems, but also some very interesting institutions capable of adaptation elsewhere.)

POINT 4

My next point is not unrelated, but has a different purpose. It is a warning that scientific effort and its technological application are frustrated unless a great complex of policy issues are attended to. My point is clearest and perhaps more complex in agriculture, but I do not believe that it is absent in the field of secondary industry.

Agricultural research is not frustrated by patents; there is a healthy relation developing between the First and Third Worlds in agricultural research and I would love to speak on this. I dare not! But let us assume that a technology is available after a full process of adapting research results to local conditions (varying all over country X). (The assumption is more realistic under irrigated conditions than for rain-fed - but let us persevere!) I will simply read you the list of matters which require policy discussion and action if the technology is assumed to be available.

1. What prices are to be assured for grain, pulses, etc? Can they be supported?

2. What storage is available in villages and in major points for grain distribution? And is the distribution system (railroads, marketing and welfare) effectively administered?

3. Are the farm inputs available:

    - seed;
    - water (irrigation or conservation practice);
    - plant protection materials or systems;
    - fertiliser;
    - power - eg for irrigation - or 'appropriate' equipment, man or beast powered.

4. Is capital available:

    - credit for farmers, especially for small farmers;

    - from national budget for public sector activities - especially those providing off-farm employment for small farmers and the landless;

    - allocation of scarce foreign exchange.

5. Is the basic technology neutral to scale? That is, is it capable of being used by small farmers? And if it is capable of being used,

are the institutions for supplying inputs and credit usable by and accessible to small farmers?

Is there a national research system capable of continuous adaptive research to tailor the basic technology to the variables of soils and climate?

6. Is there an effective extension system available to spread the awareness of the feasible and economic technology we have provided?

   Are the training systems available and adequate to sustain both research and extension activities?

7. I have already referred to the problem of appropriate institutions being available.

8. Motive: There has to be a strong political will. For the most part the threat of widespread starvation is now a sufficient spur, but, alas, it cannot be taken for granted. Without this motive the priority necessary in the allocation of resources will be inadequate.

POINT 5

The inferences to be drawn from this list are several. I will confine myself to those which seem relevant to the interests of people at this Workshop.

(a) Science and technology are to be seen as essential ingredients in raising living standards in poor countries, but they are not sufficient. Awareness of this will moderate the feeling of frustration likely to occur in all 'cooperative assistance' programs (I have adopted a modification of Gurnett-Smith's terminology).

(b) It is important to observe also that all items in the above list are themselves items for research and development of technology. Many are already matters for 'cooperative assistance'. I cite grain storage simply as one item in which Australia's comparative advantage is high.

(c) There is very considerable room for joint study programs (and participation in efforts to transfer both science and technologies) on the part of our host Academy, Social Sciences and Technology - with the Humanities watching to see that we do not dehumanise ourselves or others in the process. This need will continue long beyond the Vienna Conference in August. I would begin with an effort to ascertain what is going on bilaterally and through multilateral agencies in relation to the transfer of science and technology to our Asian and Pacific neighbours. In this I believe ADAB could play a useful role.

CONCLUSION

I conclude by saying, along with all the speakers, that the problems before this Workshop are complex. I will refrain from commenting on life's difficulty or easiness; but I want to say that I am not given to any sense of hopelessness. As I said in my opening remarks, I do not expect August be to a climax. But I do expect further progress in the area of 'cooperative assistance', already so evident when you get closer to the real action in the world of bilateral and multilateral activities in the field of science and technology transfer from developed to developing countries. Vienna will, in net, contribute to this, no matter what the political divisions paraded.

APPENDIX A - Statistical Appendix

TABLE 1

	Aust.	Can.	Sweden	Holl.	Switz.	UK	Jap.	W.Germ.	A
% of world pop. 1973	0.35	0.58	0.21	0.35	0.16	1.41	2.84	1.55	5.42
GERD* as % of GDP 1973	1.2	1.1	1.6	1.8	1.9	2.1	1.7	2.0	2.3
GERD per head US$ 1973	67	61	101	83	Est. about 125	58	67	110	146
PUBLICATIONS									
Publications in natural sciences about 614,700	9800 about 1.6% of total	20900	7400	6100	8000	40500	23300	39300	197800
Ranking in publications (absolute)	9	6	after Aust.		10	2	4	3	1
Ranking in publication per billion US$ GDP	6	3	7 after Aust.	13	4	2	14	9	5
PATENTS (1975)									
Patents owned overseas as % of world total	0.31 ranking 15th	0.97	1.67	1.95	4.05	4.80	6.12	13.04	20.16
Patents owned overseas per million population	139 ranking 18th	184	844	461	2503	422	502	784	504
Patents granted per billion US$ GDP	21 ranking 22nd	26	105	83	300	113	116	121	71
Ratio of patents obtained overseas to patents granted at home to overseas patentees	0.08 ranking 22nd	0.15	0.70	1.72	1.23	0.46	1.90	2.40	4.28

Data from Tables 2, 3 and 4 relate to period 1973/75 (see primary references), hence not fully comparable between all rows.

TABLE 2

GERD as a Proportion of GDP for some OECD Countries 1973

(excluding the humanities and social sciences)

Country	Population M.	GDP per capita US$	GERD US$ M.	GERD per capita US$	GERD % of GDP
Australia	13.3	4900	880	67	1.2*
Canada	22.13	5408	1350	61	1.1
France	52.18	4904	4350	83	1.7
Germany	61.97	5614	6810	110	2.0
Ireland	3.09	2181	50	16	0.7
Japan	108.35	3755	7220	67	1.7
Netherlands	13.44	4408	1110	83	1.8
New Zealand	2.92	N.A.	70	24	0.9
Norway	3.93	3730	160	41	1.1
Portugal	8.59	N.A.	30	3	0.3
Spain	34.37	1303	150	4	0.3
Sweden	8.14	6135	820	101	1.6
United Kingdom	55.88	2759	3260	58	2.1
United States	208.84	5589	30430	146	2.3

* If social sciences and humanities are included this figure is 1.3%.

SOURCE: Project SCORE, Research & Development in Australia 1973-74 Vol. 2 p57

TABLE 3

Publications per US$ Billion GDP

Country	Total publications (1975)	Ranking	GDP US$ billions (1976)	Publications per US$ billion GDP	Ranking
Israel	6100	13	12.6	487	1
U.K.	40500	2	219	185	2
Switzerland	8000	10	56	142	3
Canada	20900	6	194	120	4
USA	197800	1	1702	116	5
Australia	9800	9	94	105	6
Sweden	7400	11	74	100	7
West Germany	39300	3	446	88	9
France	28900	4	347	83	10
Holland	6100	12	90	68	13
Japan	23300	5	555	42	14

SOURCE: "Publication Output in the Sciences", Bakker and K. Chang. Science and Public Policy, Vol. 6 1977 p563-4, and GDP from OECD, ECON. Survey, Australia, 1978

TABLE 4

Ranking of Countries (1975) as to Patent Property Throughout World as a Measure of Technology Output

The table was prepared from World International Property Organisation (WIPO), International Bureau, 'Statistics for 1975' updated in June 1977 and from GDP and population data in UN Monthly Bulletin of Statistics, May 1977. Patents are classed as 'domestic' or 'overseas' depending on whether the patentee has filed in his own country or overseas. The 'overseas' total is a measure of international technology/techno-commercial strength.

	Patents owned overseas % of world total 1			Patents owned overseas per million population 2			Patents owned overseas per billion US$ GDP 3			Ratio of patents obtained overseas to patents granted at home to foreign patentees 4	
1.	USA	20.16	1.	Switzerland	2503	1.	Switzerland	300	1.	Germany	4.28
2.	West Germany	13.04	2.	Sweden	844	2.	Czechoslovakia	138	2.	USA	2.40
3.	Japan	6.12	3.	Germany	784	3.	Germany	121	3.	Japan	1.90
4.	France	5.05	4.	USA	504	4.	Japan	116	4.	Netherlands	1.72
5.	UK	4.80	.	Japan	502	5.	UK	113	5.	France	1.63
6.	Switzerland	4.05	6.	Netherlands	461	6.	Sweden	105	6.	Switzerland	1.23
7.	Italy	1.97	7.	Austria	424	7.	Poland	103	7.	Finland	0.72
8.	Netherlands	1.95	8.	UK	422	8.	Netherlands	83	8.	Sweden	0.70
9.	Sweden	1.67	9.	France	383	9.	Austria	82	9.	Denmark	0.56
10.	Canada	0.97	10.	Czechoslovakia	37[illegible]	10.	Greece	72	10.	Czechoslovakia	0.53
11.	Belgium	0.70	11.	Belgium	321	11.	USA	71	11.	UK	0.46
12.	Austria	0.66	12.	Denmark	285	12.	France	70	12.	Austria	0.34
13.	Denmark	0.[illegible]1	13.	Finland	207	13.	Belgium	54	13.	Yugoslavia	0.24
14.	Czechoslovakia	0.34	14.	Poland	207	14.	Argentina	50	14.	Belgium	0.17
15.	AUSTRALIA	0.31	15.	Canada	184	15.	Israel	46	15.	Canada	0.15
16.	Spain	0.28	16.	Greece	150	16.	Denmark	44	16.	Israel	0.15
17.	Finland	0.25	17.	Israel	148	17.	Portugal	36	17.	Greece	0.13
18.	Poland	0.13	18.	AUSTRALIA	139	18.	Italy	36	18.	Norway	0.13
19.	Israel	0.10	19.	Norway	130	19.	Norway	35	19.	Ireland	0.12
20.	Norway	0.08	20.	Italy	107	20.	Canada	26	20.	Spain	0.11
21.	New Zealand	0.07	21.	Spain	79	21.	Ireland	24	21.	Poland	0.11
22.	Argentina	0.04	22.	New Zealand	69	22.	AUSTRALIA	21	22.	AUSTRALIA	0.08
23.	Ireland	0.04	23.	Ireland	47	23.	New Zealand	29	23.	Argentina	0.05
24.	Yugoslavia	0.03	24.	Argentina	44	24.	Yugloslavia	7	24.	India	0.04
25.	Greece	0.02	25.	Portugal	13						
26.	India	0.02	26.	Yugoslavia	9						
			27.	Philippines	2						

Column 3 eliminates the scale effect of the national economy in that it gives national patent productivity per one billion GDP.

Column 4 states how many patents each country obtained throughout the world for each patent it granted to nationals of other countries.

TABLE 5

Ratio of Government R&D to Industrial R&D

GERD in OECD Member Countries - by sector of performance
and source of funds (natural sciences only)

Country	Sector of performance (%)				Source of funds (%)		
	Government	Business enterprise	Higher education	Private non-profit	Government	Business enterprise	Other (a)
Australia	40.6	41.3	17.2	0.9	56.7	40.2	3.1
Austria	0.0	49.0	0.0	51.0	54.0	45.0	1.0
Belgium	16.0	57.5	26.2	0.4	N.A.	N.A.	N.A.
Canada	33.0	36.0	31.0	0.0	67.5	28.3	4.2
Denmark	24.2	50.7	24.1	1.0	N.A.	N.A.	N.A.
Finland	19.1	60.0	19.1	1.8	N.A.	N.A.	N.A.
France	25.0	59.4	14.4	1.2	56.9	39.1	4.0
Germany	15.4	64.7	19.7	0.2	47.1	51.4	1.5
Ireland	50.0	33.9	13.9	2.2	57.3	37.2	5.5
Japan	13.2	65.7	18.1	3.0	33.2	66.3	0.5
Netherlands	19.9	58.5	19.6	2.0	40.3	54.3	5.4
New Zealand	65.2	23.8	10.2	0.8	77.1	21.4	1.5
Norway	19.2	49.6	30.5	0.6	59.7	37.8	2.5
Portugal	53.6	27.6	15.0	3.8	65.9	27.6	6.5
Spain	47.0	47.7	5.3	0.0	50.8	47.8	1.4
Sweden	8.3	67.0	24.6	0.0	42.2	54.3	3.5
United Kingdom	25.7	63.2	8.8	2.3	48.7	43.6	7.7
United States	15.0	69.0	12.0	4.0	54.0	42.0	4.0

SOURCE: OECD/DSTI Science Resources Bulletin, No. 1, Paris, 1976
(a) Higher Education, Private Non-profit and overseas sources

TABLE 6

EMPLOYMENT

The Distribution of Workforce in Economic Sectors
Employment by Economic Sector (%)

Country Economic sector	Mining	Agriculture	Mfg. industries	Tertiary industries
Australia[1] 1976	1.2	6.3	21.7	70.9
USA[2] 1975	0.8	3.9	23.0	72.3
Japan[2] 1975	0.3	12.7	25.7	61.3
Germany[2] 1975	1.4	6.5	34.9	57.2
Italy[2] 1976	1.7	15.3	30.9	52.1

SOURCES:

1. White Paper on Manufacturing Industry, May 1977.
2. Yearbook of Labour Statistics, International Labour Organization, 1977

TABLE 7

Country	Agriculture	Mining	Electrical Group	Chemical Group	Aircraft	Transport	Metals Group	Machinery	Chemicals Linked Gr *	Mfg. n.e.c.	Services
Australia	1.7	e	e	11.6	21.9		5.9	21.0	5.7	7.5	25.1
USA	e	e	25.5	12.4	24.1	11.7	2.6	14.6	3.0	2.8	3.4
Japan	0.1	0.6	26.2	19.3	e	16.5	7.7	9.0	5.8	7.1	7.6
Germany	0	1.4	26.6	24.9	9.2	11.9	3.0	13.0	2.3	0.9	2.9
Canada	0	5.3	25.2	15.7	11.1	3.2	9.2	8.9	4.9	6.5	6.8
Sweden	1.4	0.5	19.2	9.1	e	22.9	12.0	14.7	4.9	6.4	8.8
Holland	[illegible].5	e	e	30.5	e	52.0	e	e	8.1	1.1	6.8
Switzerland	0	0	0.2	50.8	0	0	45.3	0	4.1	[illegible]	1.1

SOURCE: Science Resources Newsletter, OECD/DSTI, No. 1 Sept. 1976 (Paris)

* Chemical Linked Group = food, drink, tobacco, textiles, footwear, leather, rubber and plastics

e = included in another sector

TABLE 8

Employment of Scientists and Engineers in R&D by Sector (%)

Country/ Sector	Government	Business enterprise*	Higher education
Australia	37.3	38.8	23.9
USA	11.9	73.4	11.9
Japan	12.0	63.5	24.5
Germany	14.6	66.0	19.4
Canada	35.1	35.3	29.6
Sweden	9.7	64.6	25.7
Holland	20.8	59.9	19.3

* Includes Private-Non-Profit

SOURCE: Science Resources Newsletter, OECD/DSTI No.1 Sept 1976 (Paris)

APPENDIX B

SOME OF THE ACTIVITIES RELEVANT TO AUSTRALIAN PREPARATIONS FOR UNCSTD

ACTIVITY	SPONSOR
Australian National Paper (1978)	Australian Steering Committee on Preparations for UNCSTD, Department of Foreign Affairs
The role of non-government organisations (1978)	Sydney Science Centre
Forestry policy and forest products in national development and the role of foreign aid (1978)	Development Studies Centre, Australian National University
The human implications of scientific and technical development (1978)	UNESCO and the Australian Commission for UNESCO
Exporting agricultural science and technology (1979)	Australian Institute of Agricultural Science
Animal health and nutrition in tropical regions (1979)	James Cook University of North Queensland
Australian grain storage research and technology for developing countries (1979)	CSIRO/Australian National University
Australian experiences of the transfer of technology and services to developing countries (1979)	Ian Clunies Ross Memorial Foundation
Current Australian Scientific Research: its application and relevance to the Third World (1979)	Development Studies Centre, Australian National University
Science and Technology - for what purpose? - An Australian perspective (1979)	Joint Academies Committee of Science, Social Sciences and Technological Sciences